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CONFERENCE ON MUSKEGON COUNTY, MICHIGAN WASTEWATER SYSTEM, SEPTEMBER 17-18, 1975

A CRITICAL REVIEW ON EVALUATIONS OF THE SYSTEM AND IDENTIFICATIONS

ENVIRONMENTAL PROTECTION AGENCY
CHICAGO, ILLINOIS

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DECEMBER 1976

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Clifford Risley, Jr., Project Officer & Director, R&D, Region V, EPA, Chicago
Ralph C. Christensen, Grants Officer, Section 108(a) Coordinator, Region V, EPA,Chicag

16. ABSTRACT

This Review Conference held September 17-18, 1975 was to provide data on the Muskegon County, Michigan Wastewater Treatment System. The operation of a municipal-industrial collection system, an aeration system, holding lagoons, and a spray irrigation system are discussed. Principal investigators of the project outline their progress from 1969-1975. Federal, State, and local government agencies are represented as to their views of the Wastewater Treatment System. Government officials, consultants and the academic community are asked for their views on research that they can see is needed to enhance the value of the project, and help to advance the status of the art in wastewater treatment on land.

The Conference discussed agricultural engineering and agricultural management of wastewater utilization, soil monitoring, groundwater monitoring and plant uptake studies. Lake monitoring, modeling and economic studies are included.

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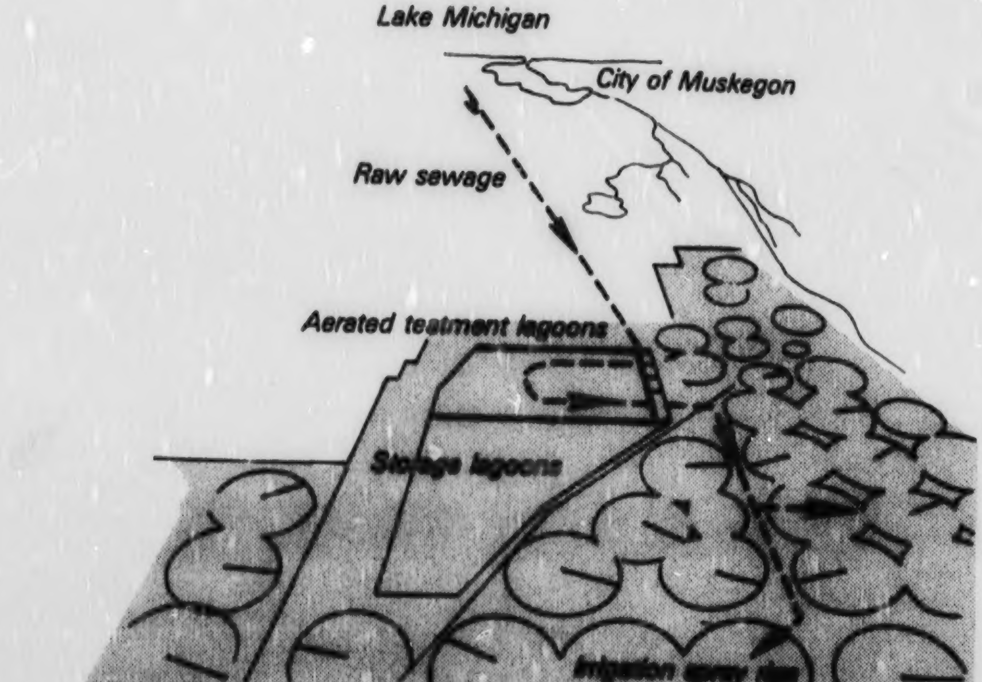
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December 1976

CONFERENCE ON MUSKEGON COUNTY, MICHIGAN WASTEWATER SYSTEM, SEPTEMBER 17-18, 1975: A CRITICAL REVIEW ON EVALUATIONS OF THE SYSTEM AND IDENTIFICATION OF NEEDED RESEARCH

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FOREWORD

The broad aims of environmental research are to identify and quantitate parameters which can be used to assess environmental impact, to devise corrective technology, and to calculate acceptable trade-offs between aesthetic and economic concerns of our affluent society. A major environmental problem has been the degradation of surface waters with disposed, improperly treated wastes. An innovative system for highly renovating and utilizing wastewater is now operating in Muskegon County, Michigan. The U.S. Environmental Protection Agency and other federal, state, and local groups have invested millions of dollars for developing and studying this land treatment system.

A National Review Conference was held in September 1975 to insure that research and development goals were being met. These goals are to learn to operate and manage the system efficiently and to evaluate its effectiveness for supplying high quality renovated wastewater at low cost, enhancing soil productivity, producing quality food, protecting groundwater, improving surface waters, and serving as a base for revitalizing the County's economy.

Participants in this conference cited the need for prompt and complete documentation of the many research and development activities. They stressed the lack and need for health effects research. They pointed out the need to study the ability of the system to strip nitrogen from the wastewater. The other most often cited research and developmental needs were (1) to determine more fully the impact of wastewater diversion on ground and surface water quality and hydrology, (2) to continue optimization of the system emphasizing steps to maintain and improve treatment performance at reduced cost, (3) to promote acceptance by the public through public involvement and by management for avoidance of health and odor problems, (4) to determine the compatibility of sludge and/or industrial wastewater application with land treatment, (5) to estimate the effective life of the system, and (6) to learn how to manage the system to prolong its effective life.

The overriding concern of the conferees was that the research and evaluation of the Muskegon System be sufficiently comprehensive and documented to provide the kind of information needed to improve operations at Muskegon and to show where and how the Muskegon experiences can be successfully transferred elsewhere. The proceedings of this conference have been transcribed and summarized herein.

ACKNOWLEDGEMENTS

This review conference was held upon the suggestion of Dr. Curtis Harlin, Chairman of the Muskegon EPA Research Advisory Committee. His efforts and interest in seeking high quality research at Muskegon, along with the very considerable foresight and leadership of Clifford Risley, Jr., the primary EPA Muskegon Project Officer, are most gratefully acknowledged. The active participation of involved research groups from Muskegon County, Michigan State University, the University of Michigan, Michigan Department of Natural Resources, and the Michigan and U.S. Geological Surveys is also most gratefully acknowledged, as is the participation of the other speakers and attendees, who helped in this overview and careful evaluation of research both underway and needed at the Muskegon County Wastewater Management System.

Everyone attending the conference was keenly aware of the gracious hospitality of Muskegon County and the generous provision by Muskegon Community College of their excellent facilities. Their support helped to make this meeting both productive and enjoyable. Dr. Demirjian and other members of the Wastewater System staff, who have operated the system so successfully and conducted much of the research, are to be highly commended for their willingness to participate in this review with us. This meeting would not have been successful without Ralph Christensen and Steve Poloncsik, who worked very hard in organizing this conference and have exercised leadership and guidance for many of the research activities at Muskegon. Finally, this report is the result of the excellent assistance of Marty Velasco and Alison Morin in transcribing, editing, and typing.

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SYNOPSIS OF PRESENTATIONS*

John Halmond, Muskegon County Commissioner, Muskegon, MI

The successful Muskegon Project stemmed from a dream about how to overcome the pollution of the County's lakes and streams. The lakes, which could have been attracting tourists and industry, were polluted by direct discharge of primary wastes by industries and many different municipalities in the County. Tourists and new industries shunned the Muskegon area and old industries were leaving. The project overcame provincialism and distrust, which stymied political consolidation and consolidation of services. It transformed the innovative idea into reality for region-wide high quality renovation of wastewater by spray irrigation with simultaneous reuse of water and nutrients from the wastewater to grow food.

The project followed careful planning and examination of the various alternatives for wastewater renovation. The decision to proceed necessitated purchase of over 10,000 acres of land and displacement of nearly 200 families. This task was accomplished with the help of long, patient hours spent by the County Board listening to complaints of persons being relocated who thought they were not being treated well. Other problems attacked were relocation of roads, rezoning, relocation of easements, obtaining quick-take authority, etc. Far-sighted leadership has been an essential ingredient.

In the future, the hope is to retain old industries and attract new ones, to stimulate an influx of tourists, and to sell the products from the wastewater farm to drastically reduce the cost of wastewater treatment. Finally, the hope is for a return in the pride of those who live in Muskegon County, and that the spirit of cooperation that now exists between the 13 governmental units who worked together to develop this wastewater system will continue in many other areas.

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* John M. Walker, Muskegon Research Coordinator for USEPA Region V, East Lansing, MI

Valdas V. Adamkus, Deputy Administrator, USEPA Region V, Chicago, IL

Continuing availability of adequate water resources is a necessity for the future sustenance and development of the nation and the quality of the lives of its people. Region V of EPA is charged with the oversight of the protection and preservation of the quality of our water resources within the Region including the Great Lakes. Lake Michigan, because of its location, is particularly sensitive to the adverse effects of man's misuse, and therefore has a special claim on EPA's attention. At a Great Lakes Enforcement conference, goals and objectives were set that formed a framework within which the imaginative plan for the Muskegon County Wastewater Management System was conceived.

Although wastewater irrigation has been practiced successfully elsewhere, the application of concepts on the scale proposed by Muskegon County had not been previously attempted elsewhere in the United States. Information was not available on the many factors which were critical to a detailed engineering design of the system. Federal and state grants were awarded to conduct feasibility studies, to build, and to evaluate the operation of the system and its impact on the environment. Great Lakes regional funds were also awarded to evaluate the impact of land treatment on soils and surface water streams and lakes within the Lake Michigan watershed.

The Muskegon Project has focused intense national, as well as regional, interest on the total management and reuse of wastewater with the recovery of nutrient resources by the use of treated wastewaters for agricultural irrigation. In May 1973, Region V established a Wastewater Management Office for the Muskegon Project to provide resident coordination of the several agencies sponsored research activities in progress here and to make available to all interested parties a readily accessible single source of reliable information concerning this effort. This conference is a direct outgrowth of this commitment of Region V.

Much remains to be learned regarding the potential of land treatment systems for effective wastewater management, both in Region V and elsewhere. The Muskegon Project represents a unique site for the study of very large land treatment systems. The efforts of the sponsors of this conference represent a most essential core of studies to better understand the design and management of such large systems elsewhere. Region V offers its encouragement and its assistance to the fullest extent to other federal and state agencies and to other institutions having an interest in the cooperative activities to enhance the scope and value of studies of the Muskegon County Wastewater System.

Clifford Risley, Jr. - Perspective, Director, Office of Research and Development,
USEPA Region V, Chicago, IL

Many of you attending this conference have been deeply involved in administration, engineering, and/or in research studies on the land application of municipal waste. This meeting was not for the purpose of exhibiting to you a completed research product; rather it is a working meeting, intended to stimulate a thoughtful, critical re-examination of the direction of the system operations, particularly the research programs which were based on the experience of one full year of successful operation and observations.

During the meeting, we want to highlight the tentative conclusions, the unusual experiences and observations. We want to subject them to critical comment and scrutiny and to compare them with other experiences for reasonableness. We want to determine, if possible, whether our data collection is being keyed to properly document the aspects of the system that are needed to establish the validity of this form of land treatment as a viable alternative for wastewater renovation.

The research on the Muskegon System has been progressively oriented toward documentation of the performance of the overall system and each of its major components. The research has been directed toward estimating the long-term impacts of the system on the surface waters and the soil resources. The research, however, has not been geared toward defining the mechanisms of treatment which occur throughout the system.

This meeting will offer an opportunity for you to evaluate the interest of all participating state and federal agencies at this meeting in relation to the Muskegon Project and to their other studies on the land application of wastewater.

William J. Bauer, President, Bauer Engineering, Inc., Chicago, IL

The system became operational in a remarkably short time. Design began in July 1970, contracts were awarded for construction in May 1971, bonds were sold in August 1971, and approximately 10,000 acres of land were acquired during the following twelve months. Aeration and storage were started in May 1973, while the irrigation system was not complete until August 1974. The system has reliably produced a high quality effluent in spite of operating before completely finished and having to overcome operational difficulties. The system appears to have additional treatment capacity over and above its design capacity and promises to give further improvements in performance and operating economy.

Selected experiences with operating the system during the start-up period are related to the original design considerations: (A) Failures in asbestos cement irrigation mains, which at first were appreciable, have now subsided, (B) Failures in buried electrical cable, which are still appreciable, are thought to be caused by either improper installation or selection of improper cable materials. (Editor's note - It has now been shown that electrical cable failures occurred because of improper grounding -- correctable by installation by inexpensive lightning arrestors) (C) The inexpensively lined irrigation canals should be modified so that sand and trash does not enter the irrigation rigs, since more problems have been encountered than anticipated, (D) The BOD of incoming wastewater is less than anticipated, resulting in the need for only about one-third of the installed horsepower for aeration, (E) Mercaptan odors are an unexpected problem at the site, arising from the paper mill wastes. Chlorination to oxidize these mercaptans and flume covering has been tried on an experimental basis. (F) Peak flows, associated with the current 27 million gallons per day (MGD) average flow, have been as anticipated. More than adequate pumping capacity is available for the full design flow of 42 MGD. (G) The sloping soil cement has been an appropriate departure from conventional step design in the storage lagoons, (H) Accumulation of solids has not created any problems, (I) Irrigation rigs are performing adequately, but get stuck in inadequately drained fields. Under drainage should be improved in some areas, (J) The direction of groundwater movement is toward the project site in accordance with the design objectives, (K) The costs for constructing the Muskegon System were not greatly different from those expected prior to the taking of construction bids, and (L) The operating costs have been low and have been offset by proceeds from crops grown in the irrigated lands.

If tackling another project, I would not change the concept but I would argue more stringently against chlorination prior to land application, I would include the effect of treatment gained through percolation of wastewater through the bottom of the storage lagoon, and I would design more measuring devices into the system. I commend the remarkable leadership of the local government of Muskegon County.

Y. Ara Demirjian, Manager-Director, Muskegon County Wastewater Management System,
Muskegon, MI

Any wastewater system as large as Muskegon's requires extensive monitoring and research for implementation of effective operation. Operational components include a collection and transmission network, biological treatment, storage, irrigation, farming, soil-crop filters, and drainage. Each of these components has been studied and monitored as has been the ground and surface water. The successful operation of this system is backed by the expertise of a broad range of disciplines in wastewater engineering, economics, politics, hydrology, limnology, and agriculture. The most important factor in the development of our management program has been our ability to make prompt use of expertise from the different disciplines and the results of research and monitoring. These efforts must be continued.

The following examples show how studies and monitoring have resulted in the system operating efficiently and economically. Preconstruction studies resulted in the design and selection of a low pressure center pivot rig for irrigation of wastewater with downward pointing nozzles to minimize aerosolization. Studies on the biological treatment cells and storage lagoons have permitted greatly reduced aeration with appreciable conservation of energy. Groundwater has not become contaminated. Wastewater seeping from the storage lagoons has been sufficiently renovated for direct discharge from the site. Discharged wastewater is meeting stringent NPDES discharge requirements. Farm productivity and management studies have resulted in rates of wastewater application at 3 to 4 inches per week during the growing season with supplemental nitrogen fertilizer only. Studies have shown that very efficient utilization of supplemental nitrogen can be obtained by injecting it in the liquid form into the irrigation channel just prior to pumping to the different fields. Improved growth and yields of crops, associated with injected nitrogen fertilizer and with modification to lessen nozzle plugging, have resulted in improved renovation of wastewater and a greater income to reduce operating costs.

Total system development costs amounted to about $42 million or about $1 per gallon per day of wastewater treatment capacity. Operational costs in 1975 are budgeted at about $2.2 million with an off-setting predicted income from the sale of the corn crop of about $0.7 million. Users in 1975 have been charged $170 per million gallons plus an additional fixed fee of $45 per million gallons.

John M. Walker, Muskegon Research Coordinator for USEPA Region V, East Lansing, MI

The transformation of such a large previously untried land spray irrigation wastewater treatment system from an idea into a successful operation in only five years is a remarkable achievement. Studies on this full-scale system have shown that it has gone far in accomplishing its goals of surface water protection by diverting and purifying wastewater before discharge and utilizing the water and pollutants to improve land and grow food to reduce the cost of wastewater treatment. Challenges and opportunities now exist for strengthening these studies to optimize management and system performance, to achieve effective low cost and long term wastewater renovation, and to verify that lagooning and land spraying is a viable alternative on a large scale for advanced treatment of wastewater.

Specific areas where additional documentation and study on the Muskegon County System are needed include: (A) Establishing water quality and hydrological balances tied to specific rates of wastewater irrigation on different crops and soils, (B) Tracing fates and movement of viruses, heavy metals, and organic compounds throughout the system, (C) Determining the health safety of foods grown on the system for direct human consumption, (D) Identifying the important socioeconomic impacts of the Muskegon County System, (E) Establishing the effects of wastewater diversion and treatment on the quality of the surface water streams and lakes in Muskegon County, (F) Establishing the minimum aeration needed to adequately pretreat wastewater, (G) Studying and taking advantage of factors which detoxify wastewater contaminants during storage in the 850-acre lagoons, (H) Determining the desirability of applying sludge to the same land used for wastewater renovation, (I) Determining the compatibility of wastewater from different industries with the land treatment systems, and (J) Determining the effectiveness of the crop-soil system for renovating the markedly different wastewaters at the Muskegon and Whitehall sites.

Boyd G. Ellis, Professor of Soil Chemistry, Michigan State University, East Lansing, MI

Land irrigation is one portion of the Wastewater Management System in Muskegon. It must be viewed as a treatment component and not just as an agriculture production system. The success of this portion of the system for treating wastewater of a given pollutant constituency and at a given rate of application is dependent upon the soil chemistry, physical properties, biochemical reactions, and living organisms. By monitoring these processes in the soil, we have hoped to understand how the system is working, to evaluate its success for long term renovation of wastewater, and to warn and predict when this portion of the system may become overloaded.

There are four major types of soils at Muskegon which react differently in their abilities to accept and drain away large quantities of wastewater and to sorb and retain different nutrients. Our results are preliminary because so little wastewater has been applied during our study period. Nonetheless, we have established a solid base level of data upon which to proceed.

Our preliminary observations and calculations indicate that elements like sodium and potassium are being applied in amounts greatly in excess of that retainable in the soil or required by crops (Editor's Note: Fortunately movement of these elements through the soil and to drainage water is not thought to pose any significant problem to ground or surface water.) We expect that phosphorus will be retained by the soils if wastewater is applied uniformly to the surface at rates of three to four inches per week (75 to 100 inches per season) and if the phosphorus content does not increase above its current low level (about 3 ppm). Nitrogen is very dynamic and retention by soil alone is small. Additional research is required to learn how to manage and balance the amount of nitrogen applied with crop and soil conditions to achieve adequate nitrogen removal. Other studies indicate that retention of heavy metals in soils appears likely without harm to crops at the low levels present in the wastewater. The ability to predict the retention of organic compounds in soils is very limited because of inadequate knowledge in this field, and the limited data collected thus far.

A. Earl Erickson, Professor of Soil Physics, Michigan State University, East
Lansing, MI

Soils have very limited abilities to retain nitrogen. If wastewater is irrigated onto land at moderate rates (as at Muskegon) without a crop-plant that is harvested, the bulk of the nitrogen applied in the wastewater will eventually leak into the drainage water as nitrate nitrogen. With continuous wastewater application, other nutrients will also eventually satisfy the capacity of the soil to sorb them and will eventually leak from the system. However, if a crop is grown and harvested nutrients are removed and recycled, better quality effluent is produced, and the life cycle of the soil is extended.

Harvesting nitrogen with a corn crop alone has the complication that most of the corn's nitrogen is absorbed from the soil in six or seven weeks in July and August, while wastewater is applied over 35 weeks. Over 20 weeks of wastewater nitrogen application, therefore, is free to leach from the soil. A possible solution to this would be to grow a cover crop which will harvest the nitrogen during the other part of the year and release the nitrogen to the corn when it is required. An example of such a system would be a within one year crop rotation of corn and rye.

There will also be sludges to be disposed of at Muskegon. The question is whether they can be used on the sandy soil there, along with the high application of wastewater, without contaminating the environment.

We are proposing a new research program to find these answers. The ability of several cropping systems to strip nitrogen will be evaluated by measuring nitrogen in weekly sample soil profiles and water from the unsaturated-saturated boundary in the soil.

John Armstrong, Associate Professor of Civil Engineering, University of Michigan,
Ann Arbor, MI

Our research deals mainly with the impact on the aquatic environment of wastewater diversion to the treatment sites. Therefore, the main emphasis in our studies has been to look at surface waters in the County by sampling 24 stations twice monthly in three major drainage basins from 1972 to 1975.

The preliminary examinations we have been able to give to our data, thus far, suggest that there has been little change during the short period after wastewater diversion. Our studies have included measurements of a limited number of chemical parameters; identification of phytoplankton, macrophytes, and benthic organisms; investigations of sediment-lake water interactions; and modeling to predict effects and performance of the three lakes as a result of diversion and other possible management techniques.

We are proposing a three-year effort to continue station monitoring and refinement and tuning of models to each lake. We also propose developing a computer simulation model of the wastewater treatment system with an examination of some of the optimal strategies that might be used to operate the lagoons and the farming operations with respect to different objectives. The one major objective, of course, is to meet water quality standards and preserve the quality of the aquatic environment. Another important objective, obviously, is to maximize the profit from crops that are grown.

Raymond Canale, Associate Professor of Civil Engineering, University of Michigan, Ann Arbor, MI

The purpose of our project is to evaluate the impact of wastewater diversion and subsequent land treatment upon surface waters of the County. The three lakes in Muskegon County which are affected are all eutrophic. They experience oxygen depletion in bottom waters in the summer with very high concentrations of both nitrogen and phosphorus occurring in lakes during parts of each year studied. Estimates are that Mona Lake is phosphorus limited, Muskegon Lake is nitrogen limited, and White Lake is on the borderline. Summer chlorophyll levels are very high in each of the lakes as in the western basin of Lake Erie. All of our conclusions must be considered as preliminary because we do not have all our data nor have we had sufficient time to analyze the data which has been collected.

Apparently there has been little change in populations of phytoplankton or macrophytes. With the rather high rates of exchange of water in the lakes each year, however, one would expect fairly rapid change. Since there has not apparently been much change, we must determine whether this is due to the short period of time since wastewater diversion, to significant continued non-point source contribution of pollutants, and/or to pollution replenishment from the nutrient-rich lake bottom sediments.

Our lake model contains chemical and biological components. It has been applied first of all to White Lake where we have a more complete understanding of diffuse and non-point source nutrient inputs and where our definitions of the existing biological and chemical situation is more advanced. We have estimated algae production as a function of nutrient concentration, light, and temperature. We have other models to predict exchange relationships between layers of water in the lake and the bottom sediments. Our next step will be to synthesize these submodels into one comprehensive model to predict impacts of wastewater diversion and other potentially applied lake management techniques on water quality. We hope to continue this research.

Paul Blakeslee, Regional Engineer, Municipal Wastewater Division, Michigan Department of Natural Resources, Lansing, MI

The responsibility for the review of planning, construction, and operations of wastewater treatment facilities in Michigan lies within the state Department of Natural Resources. The review of the Muskegon County project was truly a team effort in which we have tried to take a balanced look at both the environmental and natural resources effects.

From the beginning with the Muskegon County project, we have tried to keep its overriding goal of being the wastewater treatment facility for the entire Muskegon Metropolitan area in perspective. It also is a large farm operation and a research facility. As reviewers and regulators we have tried to balance its primary role for wastewater treatment on a continuing basis with its many other possibilities for use. Examples of potential conflict include multiple site use (recreation--hunting and snowmobiling, industrial development, and landfill area), cropping for economic return versus optimization for wastewater renovation, and even operation of the system components under stress conditions for research purposes.

We require monitoring to insure that there is avoidance of adverse groundwater impact off-site as per the design. We required resident relocation from the site rather than intermixing private ownership because of unknown potential health related problems. Buffer zones and specially designed spraying systems were installed to minimize public contact with wastewater aerosols.

The Michigan Department of Natural Resources cooperated with EPA, Michigan State University, the University of Michigan, and Muskegon County in research projects. In these studies the impacts of the system were evaluated on soils and groundwater and on downstream, surface streams and lakes. The questions were asked: Can the anticipated high levels of performance of the crop-soil filter be sustained? Over what time period can these results be achieved? What can be done to extend the useful life of the system?

We need to know the costs of each of these kinds of improvements in wastewater treatment technology i.e., what we are giving up and gaining in terms of resources. We have been asking the County to provide us with very detailed ongoing operational information each month because of its system's uniqueness and our hope that we can translate experiences from the Muskegon County System with realism to other facilities and proposals. Translation of information and experiences from Muskegon to these other facilities and proposals without adequate study, documentation, and consideration are prone to disaster.

William B. Fleck, Hydrologist, U.S. Geological Survey, Okemos, MI

Considerable progress has been made by the U.S. Geological Survey in cooperation with the Michigan Geological Survey in establishing a model to successfully predict the effects of the Muskegon County land treatment system on ground and surface water hydrology in the area. Data is being collected for development of the model on height of the water table in groundwater observation wells and on flows of groundwater and surface water drainage and discharging from the site.

The model hopefully will be refined to permit the estimation of the impact on the localized hydrology of ground and surface waters of wastewater storage and of spraying different amounts of wastewater onto the soil each week at Muskegon. Hopefully the study can be expanded, if resources permit, to develop a transport model to predict in addition movement of associated wastewater contaminants through the soil under the lagoons and through the crop-soil filter in the irrigated fields into the ground and surface water.

William A. Rosenkranz, Director, Division Waste Management Research, Office of
Research and Development, USEPA, Washington, D.C.

There is still an obvious lack of quantitative data to delineate the balance between the beneficial and adverse influence of crop land irrigation with municipal effluents. Examples are cited of studies underway to gain some of this information on the different land wastewater treatment modes: crop land sprinkler irrigation (as at Muskegon County), infiltration-percolation (as at Lake George), and overland flow (as being studied in Ada, Oklahoma). The cooperative expertise of specialists from federal, state, university, and local agencies is needed to gain this data.

Although much progress has been made in the more rational design of land treatment systems, more adequate evaluation of systems such as at Muskegon are necessary for determining more cost effective design criteria and operating modes. In this evaluation of the Muskegon County System should be a special emphasis on resolving health related issues, odor control, long-term ecological effects, and social acceptance. Resolution of these issues are critical for resolution of problems associated with site selection and availability.

Roy Albert, Deputy Assistant Administrator, Office of Health and Ecological
Effects Research, USEPA, Washington, D.C.

EPA's Health Research Program on exposure-dose-effect relationships are run to provide the health intelligence required for issuing permits, guidelines and criteria, or for promulgating standards. Such information is also used to evaluate the potential health impact of options for pollution control. In promulgating standards, we want to insure that the standard is placed on the continuum and that the margin of safety is adequate, so that health is fully protected but that overly stringent or costly controls are not required.

In the water quality portion of the program, our health research is directed toward developing criteria for the safe treatment and disposal of wastewater and sludges and for protection of fresh and marine recreational waters. Perhaps one of our biggest dilemmas is maintaining continuity and diversity in the research, that is, planning and conducting the program to allow for more than short-term pursuance of research on long-term effects, as well as for flexibility to study emerging issues. It is important to address fully both known problems, as well as emerging issues, so that rational decisions can be made to protect our environment and ultimately our public health.

Belford L. Seabrook, Sanitary Engineer-Consultant, Office of Water Programs Operations, USEPA, Washington, D.C.

Land treatment of wastewater is not new and has been a significant factor in past and current management of wastewater from many sources including highway and street storm drains, animal feedlots, agricultural food processing, municipalities, and industries. The use of land treatment is evolving from a disposal concept to a concept of treatment, utilization, and reuse and where appropriate can play a significant role in future wastewater management plans.

Much is known about the beneficial uses of wastewater, such as crop irrigation in arid zones, removal of nitrogen and phosphorus, strip mine reclamation, and reuse by industry. Some of the unknown factors are the adverse health effects, public speculation about potential health hazards, and the full cost of land application, that is, the legal and social costs contrasted with the economic value of the beneficial uses.

Much can and is being learned from studies of these older existing utilization or disposal systems. Results of an EPA commissioned survey of existing land treatment systems are summarized. While wastewater disposal and utilization projects may provide some information which can be extrapolated or used to predict the performance of land treatment systems, they are not directly comparable and continued and expanded evaluation of bonafide land treatment systems like at Muskegon are essential. Appropriate laws and regulations relating to the construction, operations, and evaluations of land treatment systems are reviewed.

Public acceptance is the primary factor limiting the use of soil treatment systems for wastewater. Close participation and involvement of the public in the planning and review of land treatment operations will help overcome this public acceptance limitation and help insure the high quality renovation of wastewater that is possible.

Harry Geyer, Director, Environmental Program, Agricultural and Natural Resources
Extension Service, USEPA, Washington, D.C.

The primary role of the Extension Service is that of education. This national service embodies the technical competence of land grant universities and their staffs throughout the United States, embracing about 16,000 professionals. They utilize research information from universities, experiment stations, the Agricultural Research Service of the U.S. Department of Agriculture as well as that of other federal agencies, and private institutions. Our responsibility is to interpret this information and get it to the appropriate audience, be it federal or local decision makers, to enable them to make rational decisions. Since we are affiliated with the Department of Agriculture, we are also interested in a system that will enhance efficiency of agricultural production. We are therefore interested in the aspects of land utilization or wastewater treatment through the land system that will contribute to efficient agricultural production.

From an educational standpoint, the Muskegon project is one from which we can learn many things. Can land treatment systems operate on privately as well as publicly owned land? We need more information on possible health related problems so that we can adequately inform those who are concerned with possible harm occurring to the health and livestock. There is also a need for information that will show the economic advantages or disadvantages of using municipal wastewater as a replacement for commercial fertilizer. The Extension Service has an established comprehensive capability for transmitting information, but without factual information it is difficult to accomplish.

Jesse Lunin, National Program Staff Specialist for Environmental Quality, USDA,
Beltsville, MD

The Agricultural Research Service (ARS) is the arm of the U.S. Department of Agriculture that conducts research on crop production and protection, livestock, soil and water resources, marketing, nutrition, and all other aspects of agriculture with the exception of those areas related to forestry. Because of its organizational structure, ARS is uniquely equipped to work on problems of regional and national significance. It also has the capability for developing multidisciplinary approaches to problems (such as relating to wastewater treatment and utilization of sewage sludges on land) which include soil and plant scientists, engineers hydrologists, chemists, etc. A key element of ARS research efforts is the inherent close cooperation with agricultural experiment stations and universities, state and federal agencies, industry, and even local municipalities.

Cooperative studies at many locations around the country are underway on maximizing beneficial use of wastewater and sewage sludge and minimizing problems that could occur from extensive quantities of nitrogen, heavy metals, and pathogens. We have had excellent results with these cooperative efforts. Information from any of these studies may be obtained from the ARS computer printout system called the Current Research Information System (CRIS) by giving appropriate key words.

Land application of wastewater is still not a well-accepted practice in the U.S. Citizens, wastewater treatment authorities, and regulatory groups are raising questions. They all need research data to give them necessary background for determining the merits of land treatment and for developing guidelines for building and operating systems that will be effective and environmentally, economically, and politically acceptable. There is a definite need for complete evaluation of these systems such as here at Muskegon. The ARS has participated and will continue to participate in such studies to the extent of its resources.

Joseph T. Callahan, Regional Hydrologist, U.S. Geological Survey, Reston, VA

For more than eighty years the Geological Survey has been engaged in studies of the streams of the United States, the groundwater systems, and the chemistry of groundwater. It is only in the last fifteen years that we have had the resources to do basic research into the physics of water movement, a basic question when we think about wastewater treatment.

Our hydrologists have learned to describe mathematically how a molecule of water will move through the soil and zone of aeration to the water table, and through the aquifer systems to areas of discharge. They have developed different types of models to predict these relationships. Hopefully our modelling efforts on the present system at Muskegon will lead to the point where one can predict how much water can be put on the land and its hydrology once applied.

Beyond physical movement of water, our interest at Muskegon would also be to determine the movement of various ions through the system. We have had some success with modelling of movement of ions like chloride in other studies, and parts of this work may be applicable here. In the long run this study and other similar studies of land treatment systems are important because not only can water be conserved and reused, but also the quality of the water and the entire environment can be improved.

Clyde Odin, Area Supervisor, U.S. Fish and Wildlife Service, Lansing, MI

Very few studies have been made by fish and wildlife people on the type of wastewater system which you have at Muskegon. Nonetheless, we are very interested in the program and the precedent which it may be setting for future wastewater management.

Since the Muskegon Wastewater System will result in improvement of the quality of receiving waters, fish and wildlife will benefit. We need to know, however, more about the impact of the treatment site itself with its 1700 acres of lagoons, available food, and lack of disturbance. Over 40,000 ducks and geese were observed on the Muskegon treatment area during the peak of migration last fall. If other land treatment systems are constructed throughout the country, their combined impacts could be quite significant. Are there dangers to short-stopping birds during their fall migration? Is there danger of transmission of pathogens or toxic substances through the food chain? Will crop depredation become a problem? Can the area be hunted without danger to the system? Similar questions should also be asked about other wildlife that will be attracted to the area.

Howard Tanner, Director, Michigan Department of Natural Resources, Lansing, MI

A land treatment system should be operated in such a manner that the soil will be enhanced and crops successfully grown in perpetuity. Not all wastes can be accepted into a treatment system and crops and rates of wastewater irrigation must be carefully selected and adjusted to the particular limits of the given situation, if the goal is to be attained.

Lack of information on virus persistence, movement, and virility during the land treatment process; lack of consulting engineers' experience with land treatment; and lack of equal consideration of all possible alternatives for wastewater treatment including energy/resource evaluations is limiting adoption of land treatment systems in Michigan like Muskegon County's. Lack of knowledge about health related questions further inhibits adoption of land treatment alternatives because it inhibits approvals for private rather than public ownership of land use for wastewater renovation.

The health safety of the Muskegon County System should be studied and documented. While land treatment is technically feasible and probably very safe now, this additional study and documentation is needed to make the system more socially and politically acceptable.

Donald Isleib, Chief Deputy Director, Michigan Department of Agriculture, Lansing, MI

The Michigan Department of Agriculture has two important roles, first, a regulatory role to protect the public food supply and second, the role of stimulating and nurturing the practice of agriculture in the state. While the regulatory role consumes a major part of our resources, the latter role is also important because Michigan is a food deficient state, importing about 50% of its food.

We have a particular concern for accidental or environmental additions of unwanted materials in foods. It is very difficult to predict what the consequences of many contaminants may be. Therefore I hope that the designers and operators of the Muskegon System and others like it will share with us the obligation to acquire the evidence necessary for conscientious regulatory performance. We hope to devote some of our resources in cooperatively obtaining and analyzing samples of food grown on systems like Muskegon's to determine their health safety.

A recycling system like Muskegon's for producing food with wastewater resources, implicitly may be something less than absolutely pure. The agriculture environment is not an aseptic environment either, nor is it a totally sanitary environment. I have no qualms that the acceptibility of agriculture products from the Muskegon system can be demonstrated. This system represents a very refreshing and appropriate application of resource management. I hope that the lessons learned here and data accumulated can be extended so that it need not apply only to lands in the public domain, and that with appropriate insights, technology, and guidelines private individuals may also share in the utilization of this resource.

Lt. Col. Donald Morelli, Assistant Chief, Planning Division, Civil Works Program,
U.S. Army Corps of Engineers, Washington, D.C.

The Corps of Engineers is vitally interested in land treatment and projects such as in Muskegon County. Their interest stems from their Congressionally mandated comprehensive studies of urban centers and the Army's need to treat wastewaters as completely and inexpensively as possible on site in their many Army bases and recreational areas around the country and world.

The Corps' Urban Studies Program considers many facets of region-wide urban planning, including evaluation of various alternatives for wastewater management with emphasis on energy and resource savings. The District Engineers are supposed to be the catalysts for the Corps that bring together all the diverse organizations and groups to implement the region-wide urban studies plan.

I am vitally interested in the community and commercial leaders here at Muskegon, who in cooperation with state and federal people, put all these diverse interests together to establish a region-wide land treatment system for wastewater management that works. I would like to take some of their experiences back for our Urban Studies people to learn by.

George Braude, Chief Chemical Industry Practices Branch, Division of Chemical
Technology, Bureau of Foods, FDA, Washington, D.C.

The Food and Drug Administration has responsibility for the safety of food and for the protection of the human and animal food chain from contamination. The Food and Drug Administration conducts surveys on dietary intakes to learn of contaminants and may establish rules, regulations, or tolerances for these contaminants including the ones potentially derived from sludge and wastewater applied to land.

At Muskegon, where wastewater is being applied that contains very low levels of heavy metals like cadmium, arsenic, lead, and selenium, the risk from heavy metal contamination because of plant uptake and food chain contamination appears low. The Food and Drug Administration is concerned, however, especially where greater quantities of heavy metals are applied to soils via sludges or more heavily contaminated wastewaters. Crops like corn tend to screen out heavy metals from the grain and thus protect the food chain. If, however, the entire corn plant were used as silage and fed to animals then far greater quantities of heavy metals could be ingested by the animals and enter the food chain posing an increased hazard.

A second area of interest and concern is microbiological. FDA microbiologists feel that the use of any form of sewage on crops in human and animal food chains could cause problems and that care has to be exercised in the pretreatment of sewage and its use. For a situation such as Muskegon's, the degree of aeration and residence time of the sewage are important parameters. So is the potential problem of the bypassing or short circuiting of treatment systems. The degree of chlorination, and its effects on the survival of pathogens, especially viruses is another area of interest and concern. Admittedly, there is only limited information on the direct correlation between sewage-borne contaminants and food-borne diseases.

A third area of FDA concern, which is perhaps more prevalent in Muskegon sewage, is with industrial and environmental organic pollutants. These may go through industrial and municipal sewage treatment systems largely unchanged, or only partly modified, and may be taken up and contaminate the food chain. In some instances, these materials are formed during chlorination within the plant. Our primary concern in these areas will be for the direct physical contamination of crops to which the sewage is applied and which may be eaten by animals. Potential accumulation and biomagnification in the fatty tissues of animals appears probable.

The risks and hazards involved in the use of sewage on land and crops in the human food chain have remained a continuing concern. Starting with the planning phase and continuing through the day by day operation of the system, persons responsible should be aware of the hazards and conduct operations in such a way to minimize risk. Additional research is needed to identify and further clarify these risks and to establish methods for their minimization.

Charles E. Pound, Vice-president, Metcalf & Eddy, Inc., Palo Alto, CA

The Muskegon County System is demonstrating that both an acceptable agricultural product and treated wastewater effluent are resulting with minimal pretreatment of wastewater. Most engineers tend to look more favorably at conventional rather than land treatment systems because of their professional training and experiences. If this situation is to be reversed, complete documentation of all aspects of the successfully operated Muskegon County System are essential. As a practicing engineer, I would like to refer to various experiences of the land treatment system at Muskegon. I am frustrated in my attempts to refer to the following experiences because of a lack of available published data.

1. Treatment performance data suggest that considerable reduction in nitrogen levels occurs during aeration and storage. Properly documented, I could use the information to design a system for appreciable removal of nitrogen by these processes.

2. Data obtained at Muskegon on organics has dealt with very specific compounds. EPA's drinking water standards categorize organics in broader terms in which data at Muskegon should also be categorized if it is to be readily transferable to other places.

3. Construction and operating costs of the Muskegon County System, which is yielding treatment comparable to AWT systems elsewhere, are significantly less than is normally encountered in constructing and operating conventional secondary wastewater treatment facilities. It is very important that we obtain documented unit costs for the Muskegon County System.

4. I would like to be assured of the effectiveness of the system for renovating wastewater. The method being used at Muskegon for sampling renovated drainage water is probably overly optimistic for showing effectiveness of the treatment system. Measurement of the wastewater percolate quality from just above the saturated zone in the soil would probably be more reliable.

I also need to know what level of aerosols can be tolerated with what degree of risk. I suggest that these answers could come from studies at Muskegon or elsewhere. Irrigation by rig and furrow application may be a feasible energy saving, aerosol avoiding partial alternative to spraying at Muskegon.

G. Morgan Powell, Project Manager, Irrigation Division, CH_2M Hill Engineers,
Denver, CO

The Wastewater Treatment System in Muskegon is apparently very successful. Because of its recently demonstrated cost effective operation, its large size, and its innovative design, its importance as a model to be studied and evaluated cannot be overemphasized. Quality reports on all phases of the system are badly needed by consultant engineers who are attempting to build new systems for other communities based upon the concept of cost effectively reutilizing resources, protecting surface and groundwater, and renovating wastewater. I urge that these reports soon be forthcoming.

Evaluations and predictions of the system's ability to renovate wastewater on the long term must be based upon more than drainage water quality analysis. Measurements of impacts in the soil profile (as well as in the aeration cells, storage lagoons, and drainage ground and surface water) is vital. Overestimations of the ability of land treatment systems to renovate wastewater are probable unless the quality of the wastewater percolate from the unsaturated zone in the soil is measured just above the water table. Specific rates of application of wastewaters of given quality to soils with different crops must be tied in with resultant water percolate quality.

Collectively, the results of these separate evaluations should be assembled, and with the aid of modelling, be used to develop a management program for system optimization. Such a model, that could be used with the proper inputs to suggest management alternatives under a range of precipitation, evapotranspiration, wastewater quality, and soil and crop conditions, would be most useful to consulting engineers.

Leo Walsh, Chairman, Department of Soil Science, University of Wisconsin,
Madison, WI

The information obtained at Muskegon County should be written up and published, even though studies conducted there have not been set up in a way to identify many of the underlying fundamental principles. Because some of these principles have not yet been sufficiently identified, it will be difficult to translate some of the Muskegon results to other potential land treatment systems.

Additional study will be needed to facilitate this translation. For example, fundamental information is needed in the Muskegon project which relates nutrient concentration in the unsaturated soil zone to the amount of wastewater nutrient applied, the uptake by the crop of the nutrient in question, and the crop yield. By using these relationships, you should be able to optimize yields and minimize nitrogen losses in the drainage water.

There are still real possibilities to reduce nitrogen losses by modifying the cropping program. For instance, there ought to be a way to establish crop growth in the fall of the year and, thus, intercept nitrogen that otherwise would be leached. If by double cropping you could get rye or some other grass established in the corn in the fall, you would do a tremendous job of recovering nitrogen applied in the fall and in the early spring. This plant absorbed nitrogen could then be recycled back through the system as organic nitrogen which would be released to the corn during the following growing season.

The compatibility of wastewater with the land part of the treatment system must be determined. A suitable balance of sodium, calcium, and magnesium must be maintained in the wastewater to avoid possible soil salinity problems.

Charles Sorber, Associate Professor of Environmental Engineering and Director,
Center for Applied Research and Technology, University of Texas,
San Antonio, TX

There has been little research at Muskegon which is directly related to health effects. Health effects research is needed at Muskegon on the safety of the wastewater grown food products for animal consumption from a potential pathogen (viral), organic, and heavy metal contaminant viewpoint. What is the life expectancy of the Muskegon system for removing these contaminants? Are migratory waterfowl adversely affected by the Muskegon system?

Not all health effects research can or should be conducted at one location. Nonetheless it is vitally important to develop sensitive quantitative detection techniques for virus. It is also extremely important to study the health effects of aerosols both with respect to spray irrigation systems as well as with conventional treatment systems. Epidemiological work, associated with wastewater treatment, is also very important and fortunately is underway at a few selected locations.

A small-scale study on aerosols was conducted at Muskegon when determining the system to choose for irrigation. Some of the monitoring information now being developed as well as the pre-design aerosol study will provide some answers valuable in evaluating health effects. It is very significant that the system has been designed to minimize adverse health effects through downward pointing low pressure spray nozzles and through ground water control and under drainage. I wish to commend Muskegon County and EPA Region V for the significant accomplishment of getting this system fully operational.

Ralph Scott, Chief, Wood Products Staff, Corvallis Field Station of Industrial
Environmental Research Laboratory, Corvallis, OR

There should be a detailed cooperative examination and documentation by Muskegon County, the U.S. Geological Survey, and Michigan State University to explain relationships among amounts of wastewater applied, cropping, soil type, and ground and surface water quality. Documentation of current studies and carefully planned additional studies are needed to show how effective wastewater treatment can be achieved with minimal input of energy. Prospective industrial and domestic municipal wastewater should not be accepted by the Muskegon County System unless determined compatible by experimental tests.

Examples are given of poor judgment and bad operation of land wastewater disposal systems that resulted in severely polluted ground and surface waters. These examples show that time is required for the effectiveness of land disposal/treatment to become apparent. While these mismanaged systems yielded apparent solutions to wastewater problems in the short run, they failed miserably in the long run as the system equilibrated.

Clifford Risley, Jr. - Summary

Because of legislative deadlines and lack of information on land treatment, construction grant money for wastewater treatment is going almost entirely for construction of conventional systems. While land treatment systems like we've seen at Muskegon may not be the answer for wastewater treatment to everyone's problem, it might be the answer to problems of many communities. These communities will not be building land treatment systems if we don't do the research now to establish the viability of the land treatment alternative.

This conference has been excellent, particularly the critique session. Stressing a few of the points made: (A) We need to document the data that has been obtained thus far, (B) We need to learn more about the levels to which crop roots can deplete nutrients like nitrogen from percolating wastewater in the root zone, (C) We need to learn more about treatment processes occurring during aeration and storage, (D) We need to establish more clearly possible health hazards involved in the operation of the Muskegon System and the use of the crops grown here, and (E) We need to be more concerned with the compatibility of industrial wastes with land treatment.

I want to thank the people of Muskegon for hosting this session for their marvelous job and to my staff who did a great deal of the work in putting this meeting together.

WELCOME AND INTRODUCTIONS

MODERATOR

Curtis Harlin*

I would like to extend my personal welcome to you to this conference on the Muskegon County Wastewater Management System.

There has been much said about this system and much printed in recent years. Some of it may be not quite accurate. We have an opportunity today and tomorrow to hear directly from those that have been involved with the program from the start; what the Muskegon County System is, what it has done, and what it is doing.

I'd like now to introduce Dr. Charles Greene, President of Muskegon Community College.

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* Chief, Water Quality Control Research Program, Robert S. Kerr Environmental Research Laboratory, USEPA Ada, Oklahoma 74820

WELCOME BY MUSKEGON COMMUNITY COLLEGE

Charles M. Greene*

Good morning to all of you. It's too bad that the sun is not shining in this warm environment up here this morning. But, I can guarantee that before you leave town you will witness lots of sunshine, if not in the sky, at least in the warmth of the hearts of the residents of this area.

It's a real pleasure for me to be here to welcome you this morning to Muskegon County and to particularly Muskegon Community College. I do this because there's a real kinship between this college and the Muskegon County Wastewater Management System.

The kinship, of course, is unique in that both the Wastewater Management System and this College serve the entire district of Western Michigan that's called Muskegon County. It's one of the two very rare total land mass service agencies that the residents of this area support.

There are some other reasons for this kinship that I think are equally important. It was with great pride that I received notice that the Marketing Club of this College had received a National First Place Award, in competition with 400 other colleges and universities across the nation in an organization called the Distributive Education Clubs of America. Our club did come in first. It came in first because of a very unique marketing and informational campaign about the Wastewater Management System. I wish you could have been at the County when we had life size billboards with our little logo theme "Willie Wastewater" and a dozen or two catchy little slogans and ideas to acquaint county residents with the idea that "Willie Wastewater - the Wastewater Management System" was going to clean up the environment in our area.

There are other reasons for this kinship in this area; the very respected Chairman of this meeting this morning, Dr. Demirjian, also serves on the faculty of this college as a Professor instructing in the area of Environmental Chemistry. With his assistance and drawing upon his broad experience, the faculty and the staff of this college have been able to develop a new associate degree program, which opened two weeks ago. This program in Chemical Technology was introduced to meet the growing and challenging needs of the chemical industries in our community and in the Management System itself.

Additionally, it gives me great pride to let you in on what we feel is the greatest boon that the Wastewater Management System has brought to this college. The heaviest concentration of chemical technicians employed at the Wastewater Management site received their basic instruction right at this college. There are many reasons for our feeling of kinship, the feeling of mutual cooperation between the college and the dramatic system of water pollution control that you are to review here, today and tomorrow.

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* President, Muskegon Community College, Muskegon, Michigan 49442

I've watched very carefully the development of this system and I've agonized with its authors over the magnitude of the early problems. As is any community, it's not easy for one from an outside agency or an outside group, and I came here from Florida about the same time that this system was developing, to move an area that is well developed into a new threshhold. But this was accomplished in this area with great pride.

Frankly we were overjoyed last year as the Muskegon County Board of Commissioners and the Board of Public Works took over the management of the system and put Dr. Demirjian in charge as its director and manager. He has dramatically reversed the operational efficiency of the crop production and cost reduction. It's a real tribute to tell you of the great leadership, the great imagination and the great talent of the man in charge, and the men that directly report to Dr. Demirjian. So, to Dr. Demirjian, the County Board Chairman Herman Ivory, to John Jurkas and to all in the County government who brought this dramatic transition to pass, my most sincere congratulations. To the distinguished Curtis Harlin, the Chief of our EPA Water Control Research program, and to each of you in attendance here today and at the Wastewater Site tomorrow, a most gracious welcome to Muskegon Community College. We consider it most appropriate that you should convene here. We also feel that it's a distinct privilege to have this assembly on our campus.

You notice this morning that our parking lots are rather confusing; that construction is going on. To give you an idea of how important the growing areas of Western Michigan are, there are two significant projects: the construction here at the college representing growth, we have nearly tripled our enrollment in the last five years, and the dramatic construction of a mall in downtown blending selected older buildings with newer buildings.

Muskegon, Muskegon County, this College, and the leadership of this community is committed to the fact that we will just not be another growing community. We will become the leading growing community in the nation. We're very pleased because of the work of the Wastewater Management System. It gave us the initial thrust to start the growth and development in this area.

We're glad you're here; I hope your stay will be as comfortable as possible. I hope you will enjoy our hospitality and our food. I certainly hope you enjoy the Bob Hope Show tonight. I found out that before I came here, he actually was here and raised money for the development of our library back in the 60's. So we have a kinship somewhere with him also.

I hope you have a marvelous two days. If the sun doesn't shine on the environment, I'm sure that the sunshine in the hearts and warmth in the welcomes of the people of Muskegon County will make you feel right at home. Thank you very much.

WELCOME BY MUSKEGON COUNTY

John Jurkas*

Ladies and gentlemen, on behalf of the Department of Public Works I'd like to welcome you to Muskegon County. We hope that your stay here will be an enjoyable one. We are honored to co-sponsor this conference composed of so many distinguished panelists.

The county is also pleased that this review and evaluation by the nation's top scientists is being conducted of our wastewater treatment facility. As with most experimental systems, the project had experienced some problems in the past. Most of these problems today are resolved.

Today the system is operating effectively and economically. Dr. Demirjian's efforts in managing and directing the wastewater system have been very instrumental in attaining these goals. I trust that the conference will be informative, successful, and beneficial to all of us, and that our experiences here will encourage others to enter into the field of land treatment facilities such as we have here in Muskegon County.

I'd now like to introduce Herman Ivory, the Chairman of our Board of Commissioners.

Herman Ivory*

Good morning to everyone. Thank you Mr. Jurkas for the introduction. Welcome to all out-of-town guests and welcome to our in-town guests. I'm going to be brief this morning, because we have other people who will be speaking later. I have assigned the task of trying to explain the intricate role of Muskegon County in the development of the system to Mr. John Halmond. What I'd like to do this morning is try to introduce a few people I have spotted in the audience and say just a little about the system.

Mr. Gordon Skipper who is sitting up high is an ex-commissioner who started from "Day One". I'd also like to introduce to you Mr. Bill Wrase of S.D. Warren. The S.D. Warren paper mill is the system's largest user. I know Mr. Wrase is here. Would you stand, Bill?

Now just a few remarks about the system. I was fortunate or either unfortunate depending on how you look at it to be with the group on "Day One" when

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* Chairman, Department of Public Works, Muskegon, Michigan

**Chairman, Board of Commissioners, Muskegon County, Michigan we conceived the idea that we would have a system. From the political standpoint it was dynamite. We had people in favor and people opposed to developing such a system. At one time we had a lot more opposed than in favor, but fortunately this comjunity was such that they were able to stay together as a Commission and have 13 political entities working together to make the system go.

I will not say anything further about the system; I will leave that for Mr. Halmond, except that a great deal of bi-partisan, bi-everything effort was involved in getting it going. I noted that as a Representative from the House, Representative Vander Jagt is here now. Would you stand please? I think you also know Bud Nagelvoort, senior staff assistant for Mr. Vander Jagt. Everyone knows that our Democratically controlled Board of Commissioners got an awful lot of support from Representative Vander Jagt, who is Republican. Significantly we are all from Muskegon County and we worked hard together.

STATE REPRESENTATIVE FROM MUSKEGON COUNTY

Tony Derezinski*

One of the many aspects which went into creating the system we have today, of course, is the political aspect. This political aspect has to be appreciated in order to get the full impact of what has been done and what will be done in the future.

One of the most happy surprises I had a few years ago was when I was stationed in Vietnam. I picked up a copy of the Saturday Review and lo and behold, I found an article about my home county, Muskegon County, Michigan, on the Muskegon Wastewater Management System. One of the main things this very interesting article pointed out was the fact of cooperation.

The cooperation was on two different levels: First of all, the project was a bi-partisan effort involving both a Democratically oriented County Board of Commissioners and a Republican Congressman representing our District in Washington getting together for progress for our community which needed a jolt in the arm to get moving again. Secondly, there was cooperation among all levels of government in order to get this project going. We had involvement in the County, subcounty (cities and townships), State, and Federal levels. The county subgroups had to work together as a cohesive unit to seek Federal and State support and funding. This was no easy task because frequently these units of government do not cooperate and see their differences and values quite at odds with each other. But all of them realized that this project was sorely needed to handle a very real pollution problem and to handle in the future a very real economic problem of a community that was in a transitional phase and needed something like this to set it off.

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Functional consolidation in this way was begun in Muskegon County. The county being the vehicle and the townships and the cities being contractual agents working together in a bi-partisan spirit to get the project off the ground. I certainly cannot take credit for any of this since I've only been in office for about nine months, but having been an observer, particularly living out in one of the townships in which the system is located, I can certainly say from that viewpoint that I'm extremely proud of being a resident of an area which pulled together like it did to put this project together and to reap the benefits that it will give us in the future.

Welcome to Muskegon County. I'm glad you all could make it and I think you will find that you are going to have an extremely informative session on a project which is a real landmark not only for the county, but for the state and I think for the country as a whole. Thank you very much.

COUNTY ROLE IN MUSKEGON PROJECT

John Halmond*

Let me begin by saying that it's a joy and a pleasure for me to be here today. Now you've never attended any meeting where a speaker said, "I wish I weren't here; I can think of ten other places I would rather be." But when I tell you it's a joy and a pleasure for me to be here, I sincerely mean that, because to me this means a turning of a chapter, the closing of an old chapter, and the opening of a new.

I was particularly hoping that all the members of the old County Board of Commissioners, the regular original board, would be here today, to savor what I would like to term victory, if I may, after all the blows that fell upon the members of the Department of Public Works, all the criticism that was heaped upon us. It seems like today is the ending of that, and the beginning of a new chapter.

I'd like to talk today about the dream that couldn't come true. I would like to break that down into five different areas; why there was a dream, what that dream was, why it couldn't come true, how it was accomplished, and the hoped for results.

To begin with: _Why the dream?_

The County Board of Commissioners and the Planning Commission recognized the fact in the late 1960's that the county's lakes and streams were becoming polluted. Perhaps our most valuable potential asset, our clean water in Mona Lake and Muskegon Lake, was being turned from an asset into a liability. We had three municipalities that were directly discharging their primary wastes into these lakes and five major industries that were dumping directly into these lakes.

These lakes should have been attracting tourists. They should have been working for us. The tourists should have been using these for fishing, swimming, water skiing, boating, and etc.

The polluted conditions of our lakes were causing old industries to move out and certainly discouraging any new industries from moving in. This aggravated an already serious unemployment condition. It contributed to something even worse - to the fact that people in this area began to lose faith and a great bulk of the citizens began to bad-mouth Muskegon County.

Now there's no one, no organization, no governmental group that can move forward if it's lost confidence and lost faith. That's the place we found ourselves in.

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Why couldn't it be done?

Firstly, this area had a long history of provincialism. Several attempts had been made at political consolidation and consolidation of services, all of which had failed. There was a lack of trust; there was great deal of mistrust.

Secondly, this project was too new. It was different. Nothing of it's kind had ever been tried on at this size before. Because it was different, there's always that human tendency to resist change.

Lastly, if it were to be done it would have to be done by the County. Now county government in Michigan is notorious for its sterility. County government is an odd form of government with no real legislative, executive, or judicial powers. Members of County Boards of Supervisors traditionally came from various units, and they represented those units. They had little interest in the overall welfare of the total area. I know very well, because I sat on the old County Board of Supervisors. We used a caucus before each meeting; the mayors of all the small cities and the area supervisors would get together and would gang up on Muskegon City and Muskegon Heights. We'd see that there'd be no progress; we were certain of that. Supervisors were expected to make a few little noises every two years during elections and then fade into the background. This was the form of government upon whom the responsibility fell to explore the unknown and do the impossible.

Even if all these things could have been overcome, we didn't have any money. The County was broke. It was in the red. In order to get these additional monies to build the project, they insisted that we first have plans. But those plans cost money. We had no money. How would like to be an elected official in a governmental unit that's already broke and then have to go out and spend money you don't have for plans for a project that may never materialize? I don't know whether we were foolish or whether we had courage. I like to think the latter. The plans were ordered and paid for.

How was this project accomplished?

The Planning Commission and the County Board reviewed various methods and techniques of wastewater treatment. They were convinced that land treatment would be the most efficient, the most economical, and most closely achieve the established objectives. Land was available at a reasonable price. It's estimated cost was about $300 per acre. The soil was sandy and well suited for land treatment. The land was marginal, mostly scrub oak. The population density was low, requiring a minimum of relocation. The distance of transmission was relatively short. I don't believe there's any place more than 10 miles. The land was flat which minimized the run-off and in addition the site could be used for multiple purposes such as recreation, power plants, landfill, etc.

It would be impossible to even begin to list all of the people who are responsible for this project. I always shudder when anyone does begin to give credit because there's always the possibility that they'll pass up someone that the fact that I'm only going to list some of the people who were responsible, I'm going to take a stab at it. Certainly, the Planning Commission; the labor leaders, who played a prominent role; businessmen and industrialists; and the County Administrator. We were fortunate that we had a man who just did not believe that there was anything that couldn't be done--he'd try anything and the more difficult it was, the harder he would throw himself into it; the Director of the DPW and Harry Knudsen, the Corporate Counsel. Harry was continually plowing new ground; no county had ever done anything like this before, and the legal ramifications would just boggle your mind. There were Dr. Bauer; Dr. Schaefer; and Rod Ditmer, who was the planner of the system at that time. I'm listing here only a few. I would like to go back and maybe pick three or four people without whose efforts, I believe, would have meant the total project collapse. They are Guy Vander Jagt, Bud Nagelvoort, who gave unselfishly of his time, and Curley Raap, the original chairman of the County Board of Commissioners. Curley had the courage and the leadership to make the total team hold together and no matter how hard the hour might seem he still had the courage to encourage us to move forward. As I mentioned earlier, Harry Knudsen; without him the project never would have come off.

It was decided that we would purchase some 10,000 acres of land. We advertised for bids from various companies to acquire the land. We came up with the idea of a flat fee plus a bonus if a specific percentage of the land was acquired within a certain time. This was necessary if we were to get the land in a hurry so the contractors could begin work. A special firm was hired to make appraisals of each and every parcel that was to be acquired. Firms were hired to conduct title research, as were firms for relocation.

The DPW board members, and Gordon Skipper is in the audience and he'll remember very well, sat in the courthouse many nights until midnight going over each and every individual purchase. They listened to complaints of those people who thought they were not being treated well, and resolved those complaints. This resulted in a minimum of condemnation procedures. It's almost unbelievable that we could acquire this much land yet had to go to condemnation so seldom. The corporate counsel, the members of the DPW board, and the county administrator spent endless hours talking to the 13 governmental units. Not only did we have to convince them in some cases to become a part of the program. In some instances we had to purchase land from them. I won't really begin to try to talk about all of the problems that were involved here, just a few more. Roads had to be closed, Indian burial grounds had to be avoided, constitutional court cases had to be fought, zoning changes were necessary, utility easements had to be relocated and legislators had to be convinced to give us quick take authority. All these problems were resolved and the project moved on.

Now, what is it we hope for and expect from this project?

We're hoping that we can retain our old industries. We're hoping that we can attract new industries that have peculiar wastewater problems. We're hoping as a result of this that employment will accelerate. We're hoping that when we clean up our lakes and streams tourist dollars will flow into this area. We're hoping that we can sell the crops from the farm and that those dollars will roll in; keeping in mind that we're talking about foreign dollars. If we can bring in a million dollars that's rolled over seven times and that's $7 million new in Muskegon County. We're hoping that the farm activities will attract other farming activities that will parallel what we're doing there. We're hoping also for a power plant, so necessary if industry is to grow, as well as the recreational experiences for citizens and tourists. Among the last things but certainly among the most important, we're hoping for a return in the pride of those who live in Muskegon County. And most importantly, we're hoping that the spirit of cooperation that exists between the 13 governmental units will continue in many other areas.

Thank you.

REGION V ROLE IN THE MUSKEGON PROJECT

Valdas V. Adamkus*

Mr. Chairman, ladies and gentlemen, I wish to express the appreciation of the Environmental Protection Agency for the gracious hospitality of Muskegon County, our host, and co-sponsor of this meeting with the Michigan Department of Natural Resources.

Our appreciation extends also to each of you who have come here today for a review of initial experiences with the Muskegon County Wastewater Management Studies. This review will explore the opportunities to cooperatively enhance our knowledge by the continuing evaluation of this large land treatment facility. Your contributions to this discussion will provide valuable insights to guide future activities of this nature.

Continuing availability of adequate suitable water resources is a necessity for the future sustenance and development of the nation and the quality of the lives of its people. The primary responsibility for preservation of water resources lies in the hands of the individual states. The Environmental Protection Agency is commissioned with oversight of the protection and preservation of the quality of the country's water resources. Region V views this aspect of the mission of the Agency with particular clarity because we have within our responsibility the Great Lakes, the world's largest fresh water resource.

The Great Lakes represent a primary source of water for the people and the industrial communities of eight states; six of which together constitute the area served by Region V. These lakes are of immeasureable value because of the aesthetic satisfaction and recreational opportunities which they so abundantly provide for us. Our concern for protection and preservation of the Great Lakes is also reinforced because the United States shares the use of this water with our neighbors, the people of Canada. The conservation of this priceless water resource is therefore a matter of significance to the nation as a whole.

Lake Michigan, among the Great Lakes, lies entirely within the boundaries of the United States and its domestic shoreline is shared by four states. Due to the head water relationship of Lake Michigan to the Lower Great Lakes, it is particularly sensitive to the adverse effects of man's misuse. By virtue of this fact, water quality of Lake Michigan may have a profound impact on the water quality in the other Great Lakes. For this reason Lake Michigan has a special claim on the attention, efforts, and the resources of Region V.

In 1968 serious concerns were developing regarding the deterioration of the water quality of Lake Michigan as a result of discharges, of inadequately treated wastewaters by communities and industries within the Lake Michigan Basin.

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At the request of the states of Michigan, Indiana, Illinois, and Wisconsin, the Federal Quality Administration (a predecessor of EPA) convened a conference to consider means by which the trend of this deterioration could be halted and reversed. This Lake Michigan Enforcement Conference concluded with recommendations and a commitment on the part of each of the conferees, that:

(1) By December 1972, the respective states should require municipalities and industries to achieve the equivalent of secondary treatment and at least 80% reduction of the total phosphorus content of wastewater discharges to Lake Michigan and its tributaries;
(2) That a unified collection system serving contiguous urban areas would be encouraged;
(3) That where needed, preliminary treatment of industrial wastes would be encouraged before discharge;
(4) And programs would be encouraged that would provide maximum use of the area-wide sewage treatment facilities rather than proliferation of small treatment plants in contiguous urbanized areas.

These objectives formed a framework within which the imaginative plan for the Muskegon County, Michigan Wastewater Management System was conceived.

The System for total wastewater management, proposed by Muskegon County in May 1969, would make these essential services available initially to over 130,000 people and to the industrial firms in seven cities and six townships in the county. The discharges of inadequately treated municipal and industrial wastes to the surface waters of the county would be eliminated and this wastewater would be brought inland for treatment by application on land. Wastewaters and their constituents would be used as resources for growing crops. The harvesting, sale, and use of crops grown on the land would complete the cycle for beneficial recovery and reuse of these waste materials.

Although wastewater irrigation has been successfully practiced elsewhere, the application of the concepts on the scale proposed by Muskegon County had not been previously attempted elsewhere in the United States, and information was not available regarding many factors which were critical to a detailed engineering design of the system. A federal grant of $43,000 was awarded to Muskegon County for the purpose of an engineering feasibility, demonstration study to develop this essential information. The report of this study, released in early 1970, provided a basis in part "for the final design of the facilities by the County's engineers and for the subsequent review and acceptance of the design by the state of Michigan and the Federal Government." So that Muskegon County might meet its newly assumed responsibilities for wastewater management services, a Federal Grant was awarded to the County in September of 1970 to assist in the costs of constructing the wastewater management system. A concurrent award of additional construction assistance monies was made by the State of Michigan. Together the response represents 80% of eligible construction costs amounting to $28 million out of the total project value of about $44 million.

Also concurrently the Federal Water Quality Administration awarded to Muskegon County a grant of about $1.5 million representing 75% of the costs of a $1.95 million study to evaluate and document the performance of the system, once it was placed into operation. The FWQA also reserved additional funds for this purpose to be applied for at a later date.

With its formation in December 1970, the Environmental Protection Agency became the custodian of this Federal commitment to water protection of the surface waters of the Great Lakes.

The signing of United States and Canadian Great Lakes Water Quality Agreement in April 1972, and the enactment of the landmark Federal Water Quality Act Amendments in October 1972, highlighted the potential of land treatment systems to achieve stringent water quality protection objectives. This event also placed significant new and increased responsibilities on EPA and on the states of the Great Lakes Basin for the protection and preservation of the Great Lakes resource.

These new responsibilities had special significance for the state of Michigan (surrounded on the three sides of Great Lakes waters). To meet the goals of the Lake Michigan Enforcement Conference a high degree of wastewater renovation would be required. A rapidly emerging interest arose in Michigan concerning the potential for high level treatment of wastewater by application and use on land. To assist Michigan and their neighboring states in obtaining data upon which to evaluate land treatment's potential, Region V awarded a grant of $250,000 in demonstration funds to the Michigan Department of Natural Resources in November of 1972. These funds provided for the conduct of additional studies valued at $690, 000 on the Muskegon County System with particular emphasis on the long term impact of this large system upon the quality of surface water resources and soils.

The Muskegon project has focused intense national, as well as Regional, interest on the total management and reuse of wastewater with the recovery of nutrient resources by the use of treated wastewaters for agricultural irrigation. In May 1973, Region V established a Wastewater Management Office for the Muskegon project to provide resident coordination of the several agency sponsored research activities in progress here and to make available to all interested parties a readily accessible single source of reliable information regarding this effort. This conference is a direct outgrow of this commitment of Region V.

Much remains to be learned regarding the potential of land treatment systems for effective wastewater management, both in Region V and elsewhere. The Muskegon Project represents a unique site for the study of very large land treatment systems in particular. The efforts of the sponsors of this conference represent a most essential core of studies to better understand the design and management of such large systems elsewhere.

Region V offers its encouragement and its assistance to the fullest extent to other federal and state agencies and to other institutions having an interest in the cooperative activities to enhance the scope and value of studies of the

Muskegon County, Michigan Wastewater Management System. You've come a long way already. We are really proud that we had input and cooperation. I really congratulate everybody from Muskegon County and everybody who participated in this great, I would say, national project which is going to serve not only the nation, but, I believe, it will be as an example in the international field.

Thank you very much.

CONFERENCE PERSPECTIVE

Clifford Risley, Jr.*

This conference was developed as an opportunity to gather together those persons who have been deeply involved in research and in studies of the land application of municipal wastes.

Our purpose in doing this was for the participants to gain an appreciation for the status of the Muskegon Wastewater Treatment System and to stimulate an exchange of information as to how the experience with this system relates to the experiences of each of the participants in their own research endeavors.

When I speak of participants, I'm referring not only to those who may have a formal place on the program, but to all of you here. This meeting was not widely publicized. We did not want to bring in all of those who might have some casual interest in the project. This meeting was by invitation to each one of you, to seek your attendance because of your own related interest in land application of wastewater. We want all of you to participate and would appreciate your comments, ideas, and suggestions during the meeting. We also encourage your continued interest and commentaries subsequent to this meeting.

This meeting was not for the purpose of exhibiting a completed research product. It is rather a working meeting, intended to stimulate a thoughtful critical re-examination of the direction of the system operations, particularly the research programs which were based on the experience of one full year of successful operation and observations.

During the meeting, we want to highlight the tentative conclusions, the unusual experiences and observations. We want to subject them to critical comment and scrutiny. We want to compare them with other experiences for reasonableness. We want to determine, if possible, whether our data collection is being keyed to properly document the aspects of the system that you are interested in and that are needed to establish the validity of this form of land treatment as a viable alternative for wastewater renovation.

The meeting must be participatory. Ample opportunities will be provided throughout the rest of the session for audience comments, questions, and exchanges with technical speakers.

The research on the Muskegon system has been progressively oriented toward documentation of the performance of the overall system and each of its major treatment components. The research has been directed toward estimating the long term impacts of the system on the surface waters and the soil resources. We want to highlight this fact, and to point out that the research has not been geared toward defining the mechanisms of treatment which occur throughout the system, i.e., it has not been geared toward pure research.

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We make this point because these purer areas of research must now be pursued. Your guidance is essential since many of you are pursuing this type of study to identify mechanisms in the treatment processes in soils. We want to program deliberate studies to optimize long-term system performance and to streamline the management philosophies for the system, in addition to performance evaluation.

While you're here, we want you to experience first-hand the magnitude of this full-scale land treatment system. Today we will be talking about it and tomorrow you will see it. I must emphasize that the system must be visited to be fully understood and appreciated. We will talk about three eight-acre biological treatment lagoons, two 850 acre storage lagoons, 6,000 acres of irrigated farmland, and 11,000 acres of total managed land, but I'm afraid to most of you these are rather incomprehensive terms. Indeed they will be until you really get out on the site and take a closer look.

You've already heard an excellent historical resume by Commissioner John Halmond. You've already heard of EPA's interest and inputs from Val Adamkus. We want you also to hear from the man who designed the system, what he has learned in following through with the construction of the system, and the implications from this for future design. We want you to hear from those who are operating the system; what their start-up experiences were; what their operating experiences are now, in terms of efficiency, water quality, manpower, and energy requirements; and the costs of the system. We will also hear from Michigan State University on what they have found in terms of physical, chemical, and biological changes in the soil resulting from the wastewater application. We will also hear from the University of Michigan on their lake monitoring and modeling studies concerning the impact of the Muskegon Wastewater Treatment System on surface water and sediment quality.

This meeting will afford an opportunity for you to evaluate the interest of the Michigan Department of Natural Resources, the Michigan Department of Agriculture, the U.S. Geological Survey, the U.S. Department of Agriculture, the U.S. Department of Interior, the Food and Drug Administration, the Army Corps of Engineers, as well as the Environmental Protection Agency in relation to the Muskegon Project and to their other studies on the land application of wastewater.

I hope that each of you will read the information we mailed prior to this meeting. It outlined our experiences to date and identified some problems and questions which we have already raised about this system and about the future of land application systems. From all of this effort, prior to and during the next two days, we hope to stimulate your thoughts and your suggestions as to how we should redirect our efforts. We need your help in identifying the highest priority areas of needed research at Muskegon and the longer term research needs for land treatment systems here and elsewhere.

Overall, we would like to foster ways in which we can all work more constructively together to accomplish more effective research.

Thank you. I hope that all the presentations you hear will help set the stage for obtaining critical suggestions and concerns from each of you.

REVIEW OF SYSTEM DESIGN PARAMETERS

William J. Bauer*

Introduction

The Muskegon County wastewater irrigation project, largest in the United States, started operations in May of 1973. Design had begun in July of 1970 and construction contracts were awarded in May of 1971. Bonds were sold in August of 1971 for the local share of the construction cost, and approximately 10,000 acres of land were acquired during the following 12 months.

Although the first water was turned into the system in May of 1973, the irrigation system was not completed until August of 1974, too late for a complete crop year. The year 1975 is thus the first year with a completed irritation system.

This paper discusses particular experiences with operations of the system during the start-up period and relates them to the original design considerations. For example, the 8" sloping soil cement lining of the storage lagoons was a deliberate departure from conventional practice of constructing soil cement wave protection on earth embankments, being very much less expensive than the conventional approach. During the first year, some ice and wave damage was experienced. The cost of repairs was about $50,000, or about 3% of the original construction cost. The second year cost of repairs was very much less. Reasons for the damaged portions appear to lie in substandard workmanship in those portions. On the whole, the 8" soil cement lining appears to have been a good choice for this type service, and the continued experience with it will strengthen support for the design criteria for this type of wave protection for earth embankments in general.

Problems with failures in insulation of buried electrical cables, with failures (mostly during construction) of asbestos cement pressure pipes, problems with clogging of nozzles, and similar difficulties are also discussed with reference to the original design criteria and assumptions.

The operating costs of the system are compared to the forecast costs as contained in the design documents, and the differences analyzed. Comparisons with costs of operating conventional treatment systems are also made. The Muskegon County system appears to be offering an unprecedentedly high degree of treatment for an unprecedentedly low price.

The reliability of the system in producing high quality effluent in spite of mechanical and electrical difficulties, the speed with which the entire system was put into operation, and the additional treatment capacity which it

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appears to have over and above its design capacity are also discussed.

The paper concludes that the project has demonstrated a remarkable degree of achievement of its goals, and gives promise of further improvements in performance and operating economy.

This condensation is developed from notes collected in anticipation of writing a paper on the Muskegon County project after the first two years of operation. It takes the form of a checklist of subjects and brief remarks about each.

Design Flows

The design flow for the first year of operation of the main part was estimated to average 28.5 MGD, and this is very nearly the actual experience. The design average capacity of 42 MGD appears ample at present. The design flow for the Whitehall system was 1.4 MGD and the initial flows were much smaller than this prior to the connection of Whitehall Leather Co. With this connection, the flows have been less than the 1.4 MGD, leaving allowance for the future connection of Montague when the sewer system for that city is complete.

Design Water Quality

Biological oxygen demand of the incoming waste is somewhat less than assumed in the design, resulting in a lesser demand for aeration. The only unexpectedly troublesome problem was in the mercaptan odors from the paper mill which are delivered to the site with the wastewater and which under certain atmospheric conditions are detectable outside of the treatment site. Chlorination of the paper mill waste was tried on an experimental basis during the summer of 1975 to oxidize the mercaptans at times when the atmospheric conditions at the site would be conducive to detection of these odors by neighbors of the treatment site.

Infiltration and Inflow

Peak flows into the system have not been any larger than expected even during periods of wet weather, in spite of the presence of combined sewers in some part of the area served. To date, the main pumping station has not exceeded about 50% of its design capacity during peak inflow periods.

Pumping Stations; Package Type

Prefabricated pumping stations installed underground were used for all stations except the Main Station C, which has a capacity of about 90 MGD. The largest of the prefabricated stations, Station D, has a capacity of about 28 MGD and has required the installation of additional cooling facilities to make it comfortable for service personnel. Minor modifications to the electrical features of these stations have been made in the first two years of operation.

Main Pumping Station C.

This 90 MGD station costing about $1.6 million was put into operation in May of 1973. Start-up problems included trouble with check valves slamming, and with operation of the flow recorder. The check valves were selected so as to minimize the problems of slamming, but in spite of this, additional equipment was required in the form of dampening devices to limit the speed of closure. The flow meter was examined many times by the manufacturer in attempts to get it to operate satisfactorily, but continued to give erratic results. No more than two of the four pumps of this station have been required to keep up with inflow, which allows plenty of capacity for future increase inflows.

Main Force Main

In addition to many miles of smaller force mains and sewers which were involved in the collection system for the project, the 66" force main 11 miles in length was an integral part of the construction project. This main has functioned in the manner intended, and it would be possible to use operating records to calculate and evaluate the hydraulic performance of this reinforced concrete pressure pipe. Such analyses should be made at regular intervals to detect the rate of aging and gradual increase in friction factor which the design assumed would occur.

Outlet from Force Main

The outlet from the force main discharges into an open flume which in turn discharges into the aerated lagoons. The open arrangement permitted easy release of gases contained in the inflow. The presence of mercaptans in the flow at this point was generally obvious to any person who visited this portion of the project. Some consideration of covering this inlet was given for the purpose of minimizing the concentration of this odor at this point. In the opinion of the writer, this move will not diminish the amount of the gas which is released into the atmosphere, but will only diffuse it over a larger area in the vicinity of the aerated lagoons.

Aerated Lagoons

The electric power required for the satisfactory operation of the aerated lagoons is a great deal less than that supplied in the design. The reason for this is the provision for future increases in flows to the system, and also provision for higher concentrations of B.O.D. of the incoming waste.

The system is functioning at about 70% of design flow rate, and the B.O.D. is about 70% of the concentration assumed in the design. Based upon these factors alone, about 50% of the installed horsepower should suffice, less the allowance in the design for spare capacity. Actually, about 1/3 of the installed horsepower has been found to be sufficient for the actual conditions encountered. Thus, the aerated lagoons appear to have a treatment capacity considerably in excess of the design value.

Solids accumulation in the aerated lagoons has not appeared to develop in the first two years of operation, at least to an extent which would interfere with the operation. With the reduced horsepower being used, it is expected that more accumulation of solids would result. Observation of this aspect of operations should be continued.

From time to time a foam problem has developed on the aerated lagoons, arising from the lignins which are present in the waste in rather high concentrations. However, this problem has been confined to the site of the project, and there appears to be no need to take any further steps to control it.

Storage Lagoons

The storage lagoons were designed to leak at a limited rate, with the leakage being intercepted and pumped back to the lagoons. This aspect functioned as designed, with the leakage rate appearing to remain essentially constant with time. Leakage rate of course varied with elevation of water in the lagoon. The effect of the passage of the water through the soil beneath the storage lagoon constitutes a treatment process in itself, and is a fruitful area of further research. Although this aspect of the project was not counted on in the original design as part of the treatment capacity of the system, it is inherently a treatment process and effectively increases the treatment capacity of the system by about 20 MGD.

Solids build up in the lagoons was estimated for design purposes to require dredging after, say, 10 years or so. Experience to date indicates that dredging will not be required for much longer than 10 years.

The wave protecting slopes around the lagoons were constructed of soil cement at an average cost of $2.50 per square yard, the total cost for approximately 630,000 sq. yds. being roughly $1.5 million. If Portland cement concrete had been used, the cost would have been about $10 per square yard, or approximately $4.5 million more. The interest on this difference in cost would have been far greater than the typical annual cost of maintenance of the soil cement, which is estimated to be less than $50,000 per year. Actual experience to date shows an average of perhaps $30,000 per year.

The 8" slab on 4:1 slope was a deliberate departure from conventional practice which uses stair-stepped horizontal slabs, one place on top of the other up the slope of the embankment. This arrangement averages several feet in thickness and is much more expensive than the 8" sloping slab. Successful performance of the more economical design has implications for wave protection on earth embankments of all types.

Irrigation Canals

Very inexpensive canals were used to carry the wastewater from the lagoon area to the irrigation pumping station. These were lined with plastic, with the plastic being covered with sand to hold it down. One canal about 4,000 feet long leads to the north pumping station, and one about 9,000 feet long leads to the south pumping station.

The design velocity in these canals was to be sufficiently low so that the movement of the sand was limited to very fine particles which would not cause any problem in either the pumping station or in the nozzles. Under the conditions during the first start-up year, however, pressures to discharge as much water as possible through the canals (to use up the unusually large volume of water stored for much longer than the design period) produced velocities which caused more sand to move than was anticipated, and some nozzle clogging resulted. Also, the vegetation and other debris along the open canals entered them and caused some nozzle plugging. Careful maintenance and cleaning of the canals and of the space along the canal is required to minimize this problem.

Enclosure of the irrigation flows in pipes would have been very expensive not only in terms of original cost, but also in terms of additional energy costs in operation. The use of the canals saved money in both counts, and is justifiable from that point of view regardless of the additional maintenance labor required to keep the system clean and orderly.

Two spillways were installed, one on each of the two irrigation canals, to afford automatic protection to the canal in the event the pumping station would be shut down while flow to the canal was being released. These were to have been constructed at the time of the original construction work, but were overlooked in the development of the construction plans.

Irrigation Pumping Stations

These outdoor type pumping stations, each about 2500 horsepower, have been functioning adequately since they were started. Some trouble with lightning was experienced, which required some repairs at one of the stations. The design pressure head at these stations is about 75 pounds per square inch. The required pressure at the pivot of each irrigation machine is about 25 psi, including the elevation head, and including the nozzle pressure of 10 psi. This leaves about 50 psi for the friction head to the most remote point in the system. As compared to conventional irrigation nozzles, the use of the 10 psi nozzle instead of typically 75 psi nozzle saves about 2000 horsepower during the operation of the irrigation system at maximum capacity. This can be an impressive saving in energy cost.

Pressure Pipelines to Irrigation Rigs

Considerable difficulty was experienced during construction with failure of the pressure pipes. These were constructed of asbestos cement and were bedded in the natural sand soils of the area. Most of these failures occurred during the time the construction contractor was attempting to make pressure tests. Some of the failures occurred at pressure as low as 20 psi, although each piece of pipe was tested at the factory at 300 psi. The design calculations showed no surge pressures which could account for such failures, and a field measurement of a pressure surge produced by a deliberate closing of a valve as rapidly as the operator would permit confirmed this analysis. The cost of replacement of the pipe was borne by the construction contractor prior to acceptance of the pipe system by the County. A few breaks are continuing to occur, and are repaired with spare pipe kept on the site for this purpose. The cause of the problem is not as yet understood. Certainly the bedding condition was ideal for any pipe, being consistently fine sand throughout the site. There is no large difference in elevation throughout the site which could produce large flow reversals in the event of power failure. There are no valves which close rapidly enough to produce excessive pressure surges. The system was designed with a calculated maximum combination of ambient plus surge pressure of 190 psi. The shut-off pressure of the pumps is about 125 psi, and the planned operating pressure at the pumping station is approximately 75 psi. Proof of the cause of this problem is still being sought at the present time. In the meantime, the system is continuing to operate, and the few additional breaks which occur are repaired as they arise.

Buried Electrical Cable

A large number of failures of the buried electrical cable occurred at places where the insulation was ruptured. Apparently the insulation was damaged during installation. Replacements and repairs were made prior to the 1975 irrigation season.

Irrigation Rigs

The irrigation rigs of the center pivot type were specified to be more rugged and durable than the conventional ones of similar size which are commonly used in farming. The reason was the very large number of operating hours per year as compared to the ordinary use on the farm, the ratio of the two being on the order of 10 to 1. To date, the greatest problem has been in the clogging of the nozzles. The original design considered the possibility of using comminuters or equivalent for the elimination of larger objects in flow furnished to the nozzles, but this approach was ruled out in the interests of keeping the system as simple as possible. Comminuters or screens would also require maintenance if they were to perform the function intended, and it was believed that the same effort expended in keeping the canal banks clean and neat would accomplish the same or better result.

Different types of tires were tried, and the rubber tire of a particular type was found to be most satisfactory for the sand areas. In a portion of the project where muck soils overly sand, limitations on irrigation amounts was found to be the best solution to the problem of excessive rutting.

Clearing of Trees

There was considerable controversy over the tree clearing operation during construction. One of the concerns was whether burning of the cleared trees would be permitted. Once the air pollution control officials had been convinced that burning could be accomplished without exceeding accepted limits, burning was permitted. Meanwhile, considerable clearing had been accomplished at extra cost through the stockpiling of cleared trees in non-farmed areas. These stacks of cleared trees still remain at the site, and are not an aesthetic attraction. Because of the large size of the project, burning of trees in the project area would have caused only tolerable concentrations of pollutants at the boundary of the site. This was the basis upon which officials eventually approved burning.

The other controversy revolved around the question of grubbing of the roots and other buried vegetation. The specifications called for grubbing only under dikes and other structures. The major portion of the cleared area was intended for farming, and no grubbing was called for there. Once the farming operations began, the roots and other buried vegetation which remained in the cleared area caused damage to cultivating equipment. The concept of the design was to plant the area mainly without cultivation, using techniques to control weeds which did not require general cultivation. The nature of the sandy soils also facilitated this approach. It was reasoned that the roots and other buried vegetation would rot under these conditions and would add to the humus of the soil. This will eventually happen, and the problems of cultivating, if cultivating is still to be used, will decrease with time.

Underdrainage

The underdrainage system appears to be functioning as designed, except for certain wet spots in the area south of Apple Avenue where muck soils prevent the water from getting into the drained sand beneath. These local problems required some local ditching and other remedial measures to drain off the excess water. The basic idea would be to channel off the water retained on the muck soils into sandy infiltration basins.

The quality of the water coming out of the drains is equal to that expected, being drinkable quality. As it then enters open ditches and moves to the points of discharge back into the natural channels, the water picks up polluting materials common to natural streams from the air and the sides and bottom of the ditch, such as insects, birds, animals, and plant debris. Thus the water is not as pure when it reaches the point of discharge into the natural streams as it was when it left the drain pipes.

The direction of movement of the groundwater is toward the project site in accordance with the design objectives. The monitoring of quality of the groundwater shows either no change or else a slight improvement as a result of the operation of the project.

Overall System Performance

The water quality objectives of the system have been accomplished in actual operation from the time the system was first put into operation. This is true even though the system was not as yet complete when the water was first turned into it, and even though a number of start up problems were experienced. The reason, of course, is that the system is inherently simple and fail-safe.

Some aspects of the performance of the system proved to surpass design expectations. Among these are the following:

1. The treatment effect of the long-term storage in the storage lagoons, which involves the percolation of the stored water through the sand underlying the lagoons and over to the interception ditch from which it was pumped back into the storage lagoons. This process also apparently includes some extensive denitrification within the storage lagoon itself, as a great deal of the nitrogen entering the lagoon appears to be lost in it. Although this is adverse to the idea of growing crops, if the treatment capacity of the storage lagoons themselves is utilized as part of the system, and only the water which is received during the growing season is used for irrigation, then the entire system can be operated in two phases:

   a) Winter storage and treatment in the storage lagoons of all water which comes to the site during the non-growing season. This would be followed by direct discharge of this water to the outlet channels of the project once it had attained the desired water quality.

   b) Irrigation of all of the wastewater received at the site during the growing season with minimal storage between the aerated lagoons and the actual application to the land. This would provide maximum concentration of nutrients in the water actually applied to growing crops.

   Operation of the system in this manner would give an effective capacity of perhaps 60 to 70 MGD as compared to the design value of 42 MGD. The hydraulic capacity of the system to deliver the wastewater to the site is about 90 MGD, providing for the ability to take some variation in flow above and below an average flow of 60 to 70 MGD.

2. The problem of removing solids from the bottom of the storage lagoons appears to be much less than anticipated. Apparently the solids are being carried out with the irrigation water and are being applied on the land. Surveys of the bottoms of the lagoons cannot account for the difference between solids coming in and solids going out with the final effluent.

One aspect of the performance, which proved to be worse than expected, is the matter of dissolved iron in that portion of the final effluent coming from the drainage pipes south of Apple Avenue. The natural iron in this soil, which was so long saturated with water because of the naturally poor drainage in the area, is now leaching out and coloring the effluent. The iron concentration in this effluent is much greater than the iron concentration in the influent. How long this condition will continue is a matter of conjecture, but it is expected eventually to diminish to more desirable levels.

Time for Construction

The time required for the construction of the project--including the time required for the purchase and acquisition of over 10,000 acres of land--was about 3 years. The project was put into operation about one year before final completion of construction because of the ability to store the water for a year or so. By contrast, the Salt Creek Plant of the Metropolitan Sanitary District, now called the John Egan Water Reclamation Plant, started to be constructed about the same time as the Muskegon County project, and is still not in operation. It appears that the simplicity of land treatment projects permits them to become operative much sooner than conventional advanced treatment plants, even when large amounts of land must be purchased.

Reliability

The performance of the system has proven to be very reliable. Other types of systems have down times or times when the inflow exceeds the treatment capacity when the quality of water discharged to waterways does not meet the desired standards. It is the practice of our profession to accept such lapses of performance as being inevitable. Yet the Muskegon County system is showing that they need not be, and that fail-safe systems can be achieved and at an economical cost.

Costs

The costs of the Muskegon County system were not greatly different from those expected prior to the taking of construction bids except for the following:

1. Land costs were considerably greater, as land selling for $170 per acre at the start of the project (based on private transactions prior to the start of the project) cost an average of about $500 per acre by the time the County acquired it. The great rise in average cost was, of course, a natural consequence of the law of supply and demand. Once the County desired the land, the price went up.

2. In addition to the cost of the land, there was a $1 million cost of relocating the residents of the land to new locations. This cost had not been anticipated in the original plan. Although funded nearly 100% with federal funds, the cost was a real cost. But it did provide corresponding benefits to those relocated. In general, every family moved into better housing as a result of the project.

3. The cost of clearing of the land was considerably more than anticipated in the original engineer's estimate. The total clearing cost was about $2 million, perhaps 20% of which arose because of the initial prohibition of the state against burning. Later this position was reversed and burning was permitted, but the major cost had been incurred by that time. This worked out to be about $500 per acre for the 4,000 acres cleared.

The operating costs (before any credit for revenue from the farm) were considerably greater than anticipated, primarily because of the great rise in costs of electricity. Offsetting this, however, was a rise in the value of the farm crops and the hope of having farm income equal or exceed total operating costs appears to be realistic according to results of the 1975 operating year. Thus, the County system may be the first to achieve 1985 effluent standards at zero cost to users of the system insofar as operating costs are concerned.

Charges to users during the first operating year were $85 per million gallons for actual operating costs, which was the figure projected from design calculations. During the second year, the rate was increased to $170 per million gallons, the increase in charges being necessary to provide for much increased cost of electrical power, for reimbursement to the County general fund for previous subsidies from that fund, to build an operating cash reserve, and for a number of other reasons.

Results of the year 1975 are forecast presently to be about $1.4 million for actual operating costs offset by a revenue from crop sales of about $1 million. The net cost per million gallons treated would then be $40 per million gallons. Actual charges to users would be more than this to provide for the aforementioned reimbursement to the County General Fund and also to build up the operating cash reserve.

It is the goal of the County to achieve a net zero operating cost wherein the income from crops and other products of the system would completely offset the actual operating costs. This appears to be entirely a reasonable goal based upon the operating experience with the system to date.

It is also the goal of the County to have new industrial developments establish themselves in the County, and the demonstrated large reserve capacity of the system to accept additional wastewater flows is a factor in being able to attract such new industry. The low cost of such treatment is another attraction to such industry.

By comparison, the cost of conventional treatment which does not produce salable commodities is continuing to rise with inflation, with costs in excess of $200 per million gallons being the general experience for the operating costs of advanced wastewater treatment plants comparable in size to the Muskegon system.

Summary and Conclusions

These remarks have been made from the standpoint of the design engineer who has followed the development of the system from the time it was conceived to the present time. It is interesting to note that the system grew out of a desire to do something about the depressed economic conditions in the Muskegon area, and not primarily out of a desire to solve a pollution problem. Only after a definition of the concrete goals of the community showed that a wastewater project which produced salable products was probably the most practical way to begin a solution to the area's economic problem was the land irrigation system proposed. The ability of the system to achieve reliable advanced wastewater treatment was in many ways a fallout from the principal objectives of a new industrial base, and more tourism.

The use of wastewater enterprises as springboards for launching economic development of an area is of course not a new idea, but the concept of using them as instruments to achieve even broader community plans is relatively novel. This paper has completely ignored this aspect of the project, simply because of limitations of time and space. It should be fully told elsewhere.

Insofar as the technical aspects of the project are concerned, I have presently only a cursory summary statement. It is my hope that additional technical papers will be written, each on one particular aspect of the project such as the soil cement lining of the storage lagoons, for example. The implications of this design, which is a deliberate departure from previous practice. have a bearing upon not only storage lagoons of wastewater irrigation projects but also upon such facilities for power plant cooling, hydroelectric developments, and for any other purpose for which earth embankments requiring wave protection might be desired.

The study of the biological and chemical processes which are taking place in the water and soil of the Muskegon project could of course occupy teams of scientists for life times. Like every other aspect of our universe, the amount to be learned is far beyond the ability of any man to comprehend and always will be. Fortunately, failure to understand the mechanics of a process does not inhibit mankind from making beneficial use of it. We don't have a complete understanding of any of the technical processes we use; we simply operate empirically. The same is true of the land treatment system.

As far as future research is concerned, I believe that more effort should be concentrated on systems which use water as the primary resting place of such unwanted materials as heavy metals, for example. I believe that less is known about such systems than is already known about systems in which the land is used as the primary resting place of such materials. Sometimes our fascination with the novel features of an unusual project like the one in Muskegon County can divert our research effort from where it is really needed. As the majority of wastewater is discharged into lakes and streams, it is there that the major thrust of research should be concentrated, particularly with regard to the question of ultimate disposal of unwanted materials like cadmium, for example.

Recommendations

If I were to tackle another project like the one in Muskegon, would I do anything differently because of my experience with it? Certainly, I would, as the foregoing paper indicates. The overall concept I would not change at all: to design a system which could produce an income and thus reduce or even eliminate operating costs, and which could serve as a springboard for other economic development.

A few particular matters which I would approach differently in designing another project of this type can be mentioned briefly:

1. I would argue much harder and I trust more effectively for omitting the chlorination prior to land application. Certainly it is not good practice to chlorinate wastewater prior to any biological treatment step, such as a trickling filter or an aeration tank. Why then is it good practice to chlorinate prior to the land application, which is also a biological process which takes place in the soil? The argument that chlorination reduces the hazards from aerosols, if valid, should also be applied to trickling filters or aeration tanks. Obviously, it

will never be so applied, but if any hazards exist, they would be more pronounced with the raw wastes being handled in the trickling filter or in the aeration tank than with the treated effluent being handled in the irrigation system. I believe the use of chlorine prior to irrigation is wasteful, unnecessary, and may also be contributing to the development of chlorine resistant organisms.

2. I would establish more completely at the outset of the project the basis for permitting the burning of cleared trees, using the permissible concentrations of particulate matter at the perimeter of the project site as a criterion. Burning would lower costs and result in a site with a much more attractive appearance.

3. I would encourage the viewpoint that the project site was actually a large conservation area, not only with respect to water and nutrients, but also with respect to wildlife of all types. I would encourage thinking which would contemplate limited hunting and fishing within the project boundaries, and would include this in the design of the project, and would officially designate it by signs and on maps as Conservation Area.

4. I would include the effect of the percolation through the sand bottoms of the storage lagoons as one of the treatment processes, and would thereby secure increased treatment capacity at a lowe unit cost. Whereas this approach would not have been possible with the Muskegon project initially, now that it can actually be observed in operation one can develop design criteria which can achieve cost savings in all future projects of this type.

5. I would design into the system more measuring devices for evaluating performances of various elements, such as pressure pipes, electrical underground cables, etc., and would require the installation contractor to make and report more comprehensive tests of such systems as a part of his construction contract.

Acknowledgments

The Muskegon County Wastewater Management System No. 1 was designed and the construction work inspected by Bauer Engineering, Inc. of Chicago, Illinois. The funds for construction came in part from grants of the U.S. Environmental Protection Agency and from the Water Resources Commission of the State of Michigan.

The officials of the County of Muskegon demonstrated during the inception of the project, throughout its construction, and are continuing to demonstrate a degree of leadership and initiative which is remarkable in local government. Without the courage and commitment of many of these persons, a project so different from the ordinary and so large in size would not have been possible. In many respects the project has been controversial. Political courage in such a climate is rare today, and I cannot close a paper such as this without calling it to the attention of the reader. I am grateful for having played a role of the design engineer in the company of such men.

PERFORMANCE AND ECONOMICS OF THE SYSTEM

Yervant A. Demirjian*

I will be presenting an overview of our system and will cover our basis for managing the Wastewater System effectively, efficiently, and economically. Any wastewater system as large as Muskegon's requires extensive monitoring for implementation of effective management. A new large-scale land treatment system, that has been previously untried like Muskegon's, must also conduct research to establish its effectiveness under different potential operational modes. The most important factor in the development of our management program has been our ability to conduct and make prompt use of research studies and monitoring observations.

The wastewater treatment operations in Muskegon are called a Management System because we are bringing together such a range of diversified disciplines. The system includes a conventional wastewater collection system, a modified form of wastewater pretreatment, and storage. The system also includes a large-scale agricultural operation involving land management, use of especially designed irrigation equipment, and large volume marketing. The agricultural part of this operation must be managed not only to make use of nutrients and water from wastewater to obtain a good crop yield (thereby reducing operational costs), but also to provide a high quality renovated wastewater effluent. It also involves a County-wide venture for revitalizing its economy. By providing inexpensive effective treatment for wastewater, older industries should be retained and new industries attracted. By cleaning up its surface streams and lakes recreational opportunities should be expanded and attracted. This system furthermore is an EPA Demonstration-Research study in which the efficiency of this system is carefully evaluated, effective management is developed, the impact on the quality of ground and surface water is measured, and how well the County is realizing its socio-economic goals is determined.

Most wastewater from the County is derived from its most densely populated region which lies between Muskegon and Mona Lakes (Figure 1). Currently, a total of 27 million gallons per day (MGD) of wastewater is diverted to the main Muskegon treatment site. A much smaller site is situated about 20 minutes north. This small site treats wastewater from several of the communities and industries surrounding White Lake. At present it has an average flow treatment capacity of about 1 MGD with 150 acres under irrigation. There are still significant areas of the County not connected to either treatment systems. I am not going to talk very much about this small project, unless there are any specific questions. My talk will be mainly concerned with the large project, which many of you will see on the tour tomorrow.

The collection system leads from many small pumping stations through a main

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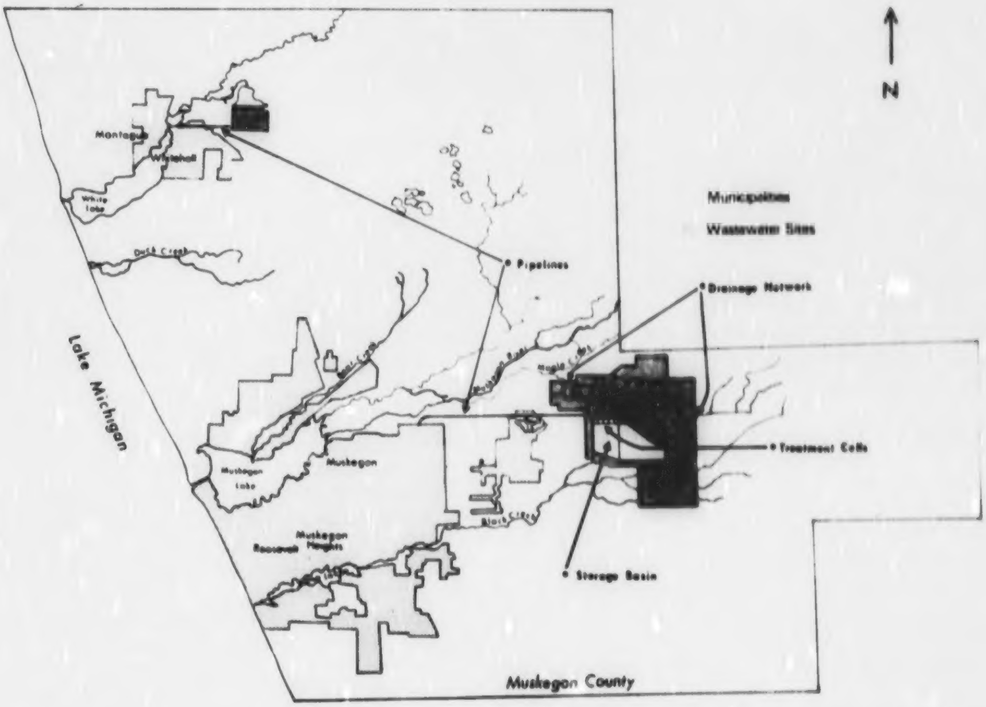
* Director and Manager, Muskegon County Wastewater Management System, Muskegon, Michigan 49442

Figure 1. Muskegon County showing densely populated areas and the small Whitehall and large Muskegon wastewater treatment sites.


N
Montague
Whitehall
White Lake
Duck Creek
Lake Michigan
Muskegon Lake
Muskegon
Muskegon River
Black Creek
Roosevelt
Muskegon Heights
Municipalities
Wastewater Sites
Pipelines
Drainage Network
Treatment Cells
Storage Basin
Muskegon County

pumping station eastward about 10 to 11 miles to the main Muskegon treatment site. Upon entering this site, wastewater undergoes biological treatment (Figure 2.) After aeration, the effluent water normally goes into storage. If we decide to irrigate the water onto land directly during high demand periods in the summer, we can direct the aerated water through a settling pond into an outlet lagoon. By circumventing the storage there is less of a reduction in wastewater nutrients. This higher nutrient content can beneficially help satisfy crop fertilizer needs. Whether storage is utilized or not, water always goes into the 14 acre outlet lagoon prior to chlorination and irrigation.

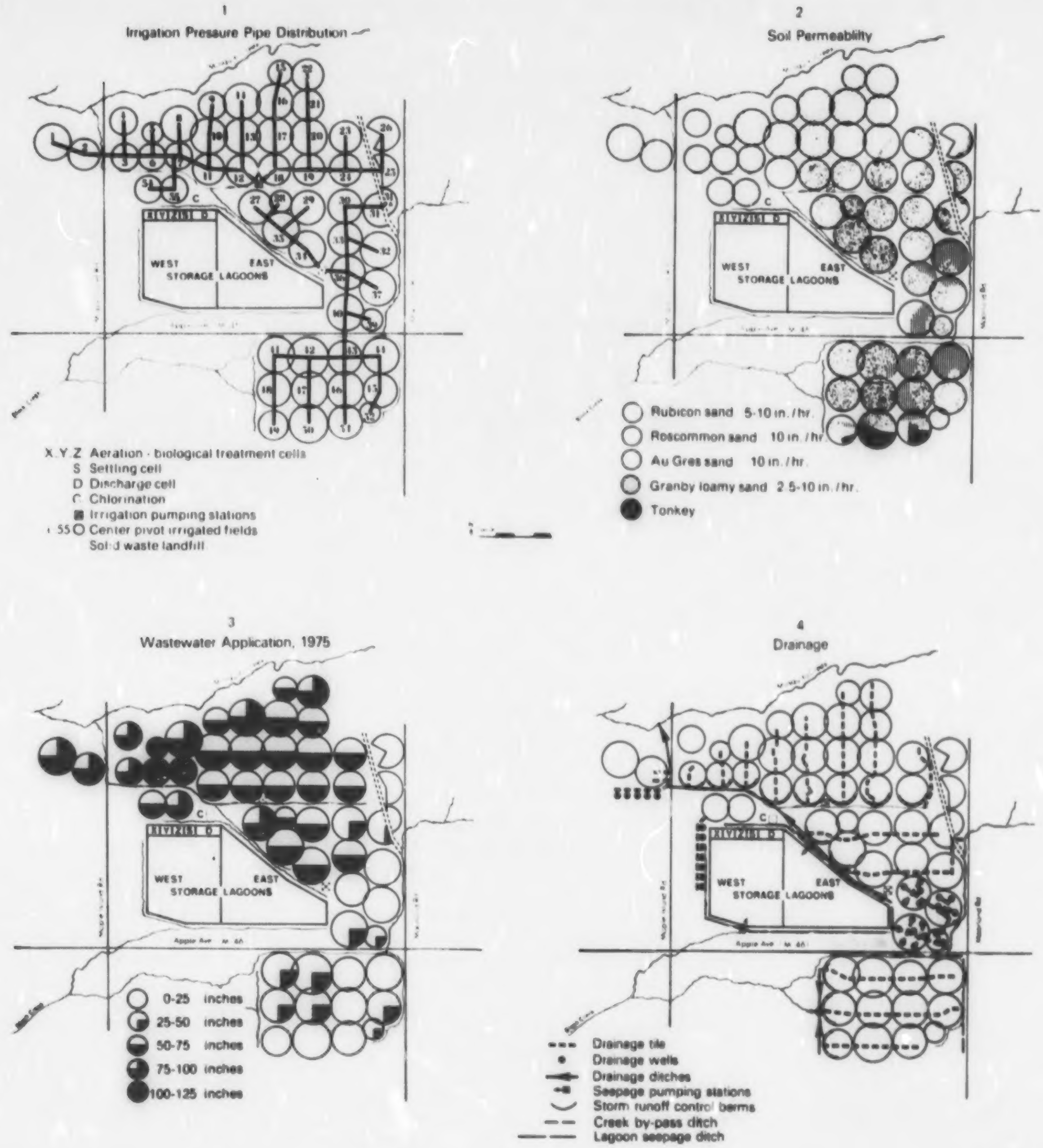
The overall size of the Muskegon site is 11,000 acres. About one-half is irrigated with wastewater and the rest is for storage of wastewater, buildings, buffer zones, industrial development, and some minor expansion. There are two storage lagoons, each with an approximate 3 billion gallon storage capacity and a total combined surface area of 1700 acres. There are 54 circular fields with sizes ranging from 35 to 140 acres that are irrigated with wastewater via center pivot rigs.

After being sprayed onto the land, water is drained from these irrigated soils by three different procedures. First of all, there is an extensive system of perforated plastic drainage tile in many of the fields. The lateral tiles are mostly spaced 500 feet apart and are approximately 5 feet below the soil surface. On the western side of the site, where the groundwater is deeper, pumps have been installed for drainage. At the upper end of the site, where the groundwater is deeper, water drains naturally through the soil into the Mosquito Creek Basin. In the south we have drain tile, which because of the soil type, is ineffective at its current 500 foot spacing. The water being drained there is pumped into the receiving stream, Black Creek. About one-third of the flow of renovated wastewater goes into Black Creek, which in turn goes into Mona Lake and finally into Lake Michigan. In the north, Mosquito Creek is the collecting stream that receives the other two-thirds of the renovated wastewater from the site. Mosquito Creek discharges into the Muskegon River, then Muskegon Lake, and finally into Lake Michigan.

I would now like to review a number of studies that have helped develop the system and improve its management. First, there were a series of pre-construction studies which involved evaluations of the irrigation machines. These included studies on wind draft, aerosol distribution, water distribution, and mechanical performance. As a result of these studies, specifications were prepared and the resultant rigs installed. These rigs featured downward pointing nozzles, low pressure operation, and wide rubber tires for transversing the fields at Muskegon. Several aspects of this study have recently been undergoing restudy and refinement. A report on this work is in the process of being written for submission to EPA.

There also have been a series of studies dealing with the operation and management of the aeration cells and storage lagoons. By carefully balancing aeration and storage, we have drastically reduced the energy consumed for aeration. When we first started, we didn't have the experience to know how much BOD we could load into the storage lagoons. It was recommended that we not load the

Figure 2. Muskegon County Wastewater Treatment System schematics.


1
Irrigation Pressure Pipe Distribution
X,Y,Z Aeration - biological treatment cells
S Settling cell
D Discharge cell
C Chlorination
Irrigation pumping stations
55 Center pivot irrigated fields
Solid waste landfill
WEST
EAST
STORAGE LAGOONS
2
Soil Permeability
Rubicon sand 5-10 in./hr.
Roscommon sand 10 in./hr.
Au Gres sand 10 in./hr.
Granby loamy sand 2.5-10 in./hr.
Tonkey
3
Wastewater Application, 1975
0-25 inches
25-50 inches
50-75 inches
75-100 inches
100-125 inches
Apple Ave M-46
4
Drainage
Drainage tile
Drainage wells
Drainage ditches
Seepage pumping stations
Storm runoff control berms
Creek by-pass ditch
Lagoon seepage ditch

storage lagoons past 20 pounds of BOD per acre. We were running the three aeration cells at full blast. Through experimentation, however, we found that you could load the storage lagoons with greater than 20 pounds BOD per acre without causing malodor. Furthermore, we were obtaining additional reduction in BOD in the storage lagoons during retention. We have been loading the storage lagoons with BOD for some time at a higher rate and they are still handling it well.

As a result of our ability to overload the storage lagoons with BOD, we reduced our aeration from running three cells full blast in series to an operation involving only two cells in series in partial operation. In effect, we are operating with the equivalent of only one cell's electrical consumption. Thus, the reduced electrical energy required for aeration this year cost about $200,000 less than last year.

We monitor this system at many different points. We monitor groundwater in 300 wells. Some are sampled every six months and others every three months. We have not seen a decrease in groundwater quality. Over 200 of the groundwater wells are situated around the storage lagoon. The rest are around the perimeter of the site. Our analysis of the water quality data on the perimeter wells show us that we are maintaining an inward flux of groundwater flow into the site. The quality of the perimeter groundwater has improved compared with preoperation. Our water quality analysis also indicated that we are drawing the groundwater towards the storage lagoons into surrounding lagoon seepage ditches.

The treatment performance studies follow the quality of wastewater from its receipt into the aeration cells all the way to its discharge after being sprayed on the land and drained into Mosquito and Black Creeks. Table 1 shows the average level of contaminants in the wastewater at different stages throughout the treatment process. It is interesting to note the average BOD and COD levels of the incoming raw sewage. COD is over 2 times as high as BOD. This is because we serve a highly industrialized area. The industrial contribution to the total effluent if 60 to 65% with the remainder being domestic. The nitrogen level is low because a large volume of the daily wastewater flow is from a paper mill. Heavy metals are low in the wastewater with the exception of iron.

You can see the efficiency of treatment of the wastewater for BOD and COD in Table 1. By the time the wastewater flows through the system there is a drop in BOD of over 98%. COD also drops dramatically from 550 ppm down to 30 to 40 ppm. The bulk of the reduction in COD and BOD occurs during aeration and storage.

Table 1 also shows what is happening to nitrogen, potassium, and phosphorus. The total nitrogen concentration was depleted from close to 15 ppm in the influent to only 2.5 ppm at the discharge point. Twenty-five percent of the removal occurred during storage. The potassium levels are coming down as well as the phosphorus. Phosphate levels are dramatically reduced with 97% less phosphate (0.05 ppm) present in the discharged effluent. The changes in the other wastewater contaminants through treatment are also shown in Table 1.

Figure 3 shows a comparison of treatment effectiveness of a conventional secondary treatment plant versus the Muskegon System. BOD levels in the treated

TABLE 1

SUMMARY OF TREATMENT PERFORMANCE

1974 Average Results

Parameter		Influent	Discharge From		Storage Lagoon		Drain Tiles	Mosquito Creek	Black Creek
			Cell 1	Cell 2	East	West			
BOD	ppm	220	105	65	20	5	2.2	2	2
DO	ppm	0	1	2	3	8.5	2-9	9.5	1.6
Temp. ^oC		24	24	20	1-26	1-26	-	1-5	12
pH		7.5	7.5	7.6	7.6	8.2	7	7.2	6.8
Sp COND umhos		1300	1100	1100	1200	750	600	750	800
TS	ppm	1050	950	1000	750	550	-	375	700
TVS	ppm	500	400	380	300	200	-	160	150
SS	ppm	325	250	250	20	10	-	10	30
COD	ppm	550	350	325	140	70	-	30	25
TOC	ppm	140	75	70	30	20	5	10	10
NH_4^+	ppm	9.0	6	4	2.5	0.2	0.40	0.45	0.5
NO_3/NO_2 ppm		0.0	0.07	0.1	2.5	0.8	2.8	1.9	1.4
PO_4^{3-}	ppm	6.5	5	5	5	0.7	0.05	0.1	0.05
SO_4^{2-}	ppm	85	100	100	95	70	140	80	320
Cl^-	ppm	175	170	170	160	90	50	60	18
Na	ppm	150	150	150	145	85	40	40	7
Ca		70	70	70	65	60	70	60	110
Mg		16	16	16	16	16	25	20	40
K		11	11	11	11	6	2.8	5	2.5
Fe		1.25	0.75	0.75	1.0	0.7	4.0	0.08	0.4
Zn		0.9	0.5	0.5	0.25	0.15	0.06	0.1	0.2
Mn		0.25	0.25	0.25	0.25	0.08	0.15	0.08	0.4
Color units						100	20-150	130	
Turbidity Jackson Units						2.8	0.1-50	4.5	
Total Coli (colonies/100 ml)						$0-1.3x10^5$	10-1000	$40-1.5x10^4$	
Fecal Coli (colonies/100 ml)						0-2400	0- 440	1-1500	
Fecal Strep (colonies/100 ml)						0-2300	2- 700	7-5500	

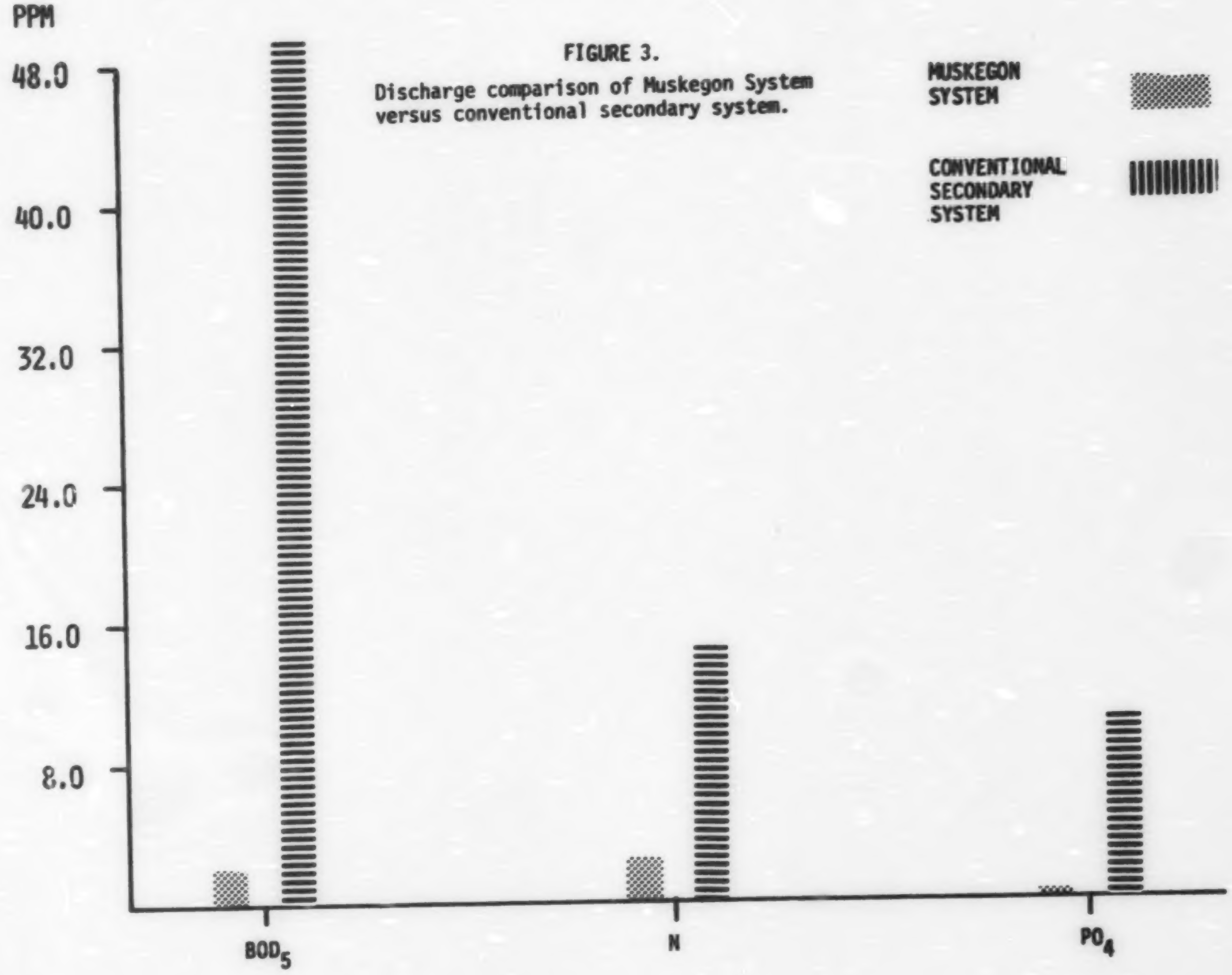


FIGURE 3.

Discharge comparison of Muskegon System versus conventional secondary system.

effluent have been reduced to about 50 ppm in the secondary treatment compared with three or four ppm at Muskegon. Nitrogen at Muskegon is only about 2 to 3 ppm compared with 10 to 12 ppm by secondary treatment, and phosphorus levels are over 10 ppm compared with much less than 1 ppm at Muskegon.

Table 2 shows the percentage of pollutants removed as the wastewater passes through this treatment system. Sixty-five percent of the BOD is removed during aeration. Even when the three aeration cells were running at full blast, only 80% of the BOD was removed. Through storage, 95% of the BOD was removed with only an additional 3% being removed by the time of discharge. Similarly for suspended solids, you will see the efficient removal; however, a lesser percentage was removed during aeration compared with a greater percentage removal during storage. We expected some solids accumulation in both the aeration cells and the storage lagoon. We found one or two feet of solids accumulating in the bottom of the aeration cells while there has been negligible accumulation of solids in the storage lagoons.

Nitrogen removals at different stages are also shown in Table 2 with 79% removal of the inorganic nitrogen at the point of treated effluent discharge. There was virtually no removal of phosphorus during aeration, 41% was removed through storage, while 99% was removed at the point of discharge. The crop-soil part of the system was essential for removing the bulk of the wastewater phosphorus.

Table 3 compares the expected removal of pollutants based upon the system design with amounts that must be removed to meet NPDES discharge limits and with amounts the system is actually discharging. The comparison shows that the system is meeting NPDES discharge limits for all parameters except fecal coliform. This is thought to be due to contamination from waterfowl. Erosion along the drainage ditches has filled in around culverts, slowed the flow, and raised the level of water making it attractive for waterfowl. We are working to remove this eroded sediment to alleviate this problem. The system is also achieving design expectations except for suspended solids. The elevated level of suspended solids results from iron leaching down through the soils out into the drain tiles. As the pH of the soil stabilizes, we expect iron leaching to subside.

Table 4 shows the loading per day throughout treatment. You see the phosphate loading is 330 pounds per day, total kjedlahl nitrogen about 2,700 pounds, BOD 48,000 pounds, suspended solids 62,000 pounds and total solids 265,000 pounds. These levels of pollutants are not too different from that found in other treatment systems.

We have calculated the cost per pound of removal of each of these pollutants. In Table 5 you see that it cost 0.9¢ per lb. to remove BOD plus suspended solids during aeration and an additional 0.4¢ per lb. to remove additional quantities of BOD and suspended solids plus considerable amounts of nitrogen and phosphorus during storage. For completing the removals by the irrigation part of the system it cost an additional 12¢ per pound. While calculations of this nature tend to exaggerate the cost for the latter treatment step, it is still evident that the storage phase of the treatment system costs the least. The actual total costs for these three steps in the treatment process were aeration - $216,000, storage

TABLE 2.

% LOADING REMOVAL

	Aeration Cells	Storage Lagoons	Irrigation Soil & Crops
BOD	65	95	98
Suspended Solids	48	96	99
N	33	66	79
P	-	41	99+

TABLE 3.

SYSTEM PERFORMANCE

Parameter	System Design	30 Day NPDES Limit	Current Effluent(1)
$B.O.D._5$	4 mg/l	4 mg/l	3.7
Suspended Solids	4 mg/l	10 mg/l	8
Total P	0.5 mg/l	0.5 mg/l	0.009
Ammonia - N	0.5 mg/l	-	0.7
Nitrate - N	5.0 mg/l	-	1.3
Fecal Coli	0	200/100 ml	238*

(1) Results cover irrigation period April through August 1975.

* This Fecal Coliform count is uniform during and off irrigation season.

TABLE 4.

LOADING - POUNDS/DAY*

Parameter	Aeration Lagoon Influent	Aeration Lagoon Effluent	Storage Lagoons	Outfalls
Soluble ortho phosphate - P	330	450	330	2
Nitrogen				
TKN - N	2,570	2,430	1,330	300
NH_3 - N	1,980	1,370	680	160
NO_3 - N	16	40	610	290
B.O.D.$_5$	48,100	15,900	2,920	760
Suspended Solids	62,200	32,000	3,860	4,650
Total Solids	265,000	213,000	160,000	135,000

* February through July 1975, average results, at 28 MGD.

TABLE 5.

UNIT PROCESSING REMOVAL COST

	Aeration Cells		Storage Lagoons		Irrigation Soil & Crops
Cost/lbs/28 MGD	0.9¢		0.4¢		12¢
Removal	BOD & Suspended Solids	plus	N & P	plus	metals

$62,000, and irrigation $250,000 (Table 8). Therefore, we are seriously considering doing additional studies on the lagoon dynamics or lagoon management to take greater advantage of this lowest cost part of the treatment system.

Obviously, our primary purpose is to renovate wastewater. Our belief has been that wastewater renovation by soils and crop utilization will be greater if our crop yield is greater, i.e., efficient management of wastewater application and supplemental use of fertilization, as needed, should result in better wastewater renovation and incidentally greater crop yields whose sale reduces the cost of operation.

Our studies on treatment performance and agricultural management and productivity have been very valuable to us in determining permissible rates of wastewater application and in establishing supplemental fertilization practices to optimize corn production and wastewater renovation. In one set of experiments run in the field on Circle 55 (Table 6), we started with one inch per week of wastewater effluent with and without supplemental fertilizer. Similarly, our treatments were 2 1/2 and 4 inches per week of wastewater effluent from storage with and without supplemental fertilizer added. The study was run for 16 weeks, during which time the crop grew and matured.

Our results indicated that application of 4 inches of wastewater effluent per week was adequate, and at this rate of application supplemental addition of potassium fertilizer was not necessary. Hence our practice this year has been to apply, where soil drainage conditions permitted, three to four inches per week of wastewater effluent without supplemental potassium.

That initial study was run, assuming the wastewater nitrogen levels would be higher than they currently are. Based on current wastewater nitrogen levels then, we calculated that about 40% of the total nitrogen requirement would have to be supplied as supplemental nitrogen. We ran a study in Circles 3 and 11 to study the effectiveness of supplemental additions of nitrogen to increase crop yield and to cause greater efficiency of nutrient removal (hence wastewater renovation). Both Circles 3 and 11 are of similar soil type and each is about 100 acres in size. Our conclusions from this research are, as we had expected, that supplemental nitrogen is required for healthy crops and healthy crops mean high quality renovation of wastewater and increased yields.

From our observations, studies, and consultations with our Farm Advisor, we decided to inject nitrogen fertilizer into the effluent wastewater in the irrigation channel just prior to spraying the fields. The amounts injected are based on crop needs, as indicated by calculation and by tissue tests, with allowances being made for nitrogen already present in the wastewater. This nitrogen was injected daily in small amounts (3 to 5 lbs.) to just satisfy crop needs. In this manner we have used less fertilizer. Less labor and equipment is required to apply this injected fertilizer than by spreading it in solid form as before. This practice has resulted in better utilization of the added nitrogen and wastewater nutrients by our corn crops.

We have had a problem with sand, weeds, and other debris getting into our irrigation system and plugging the nozzles. Our crops have suffered considerably

Table 6.

Wastewater Treatment	Total Wastewater Applied	Total Added Nutrients N	P	K	Corn Yield
inches/week	inches	-- pounds/acre --			bu/acre
1	16	14	5	35	74
1+ fert*	16	14	5	160	44
2.5	40	36	13	87	65
2.5+ fert*	40	36	13	212	85
4.0	64	58	21	139	84
4.0+ fert*	64	58	21	264	90

* 125 pounds per acre K

where the nozzles have been plugged and where they therefore received no wastewater. Considerable labor has been required to continually clean out the nozzles. We have run trials with different types of screens to see if we could alleviate the nozzle plugging problem. Our plans now are to install a sump in the irrigation channel to trap sand and to install manually changed screens in the irrigation channel just before the water enters the pumps. We plan to make these modifications at one of the two irrigation pumping stations next year and follow up at the other in 1977 if this procedure proves effective. Step-wise modifications of this nature are proving very wise for us and are being accomplished with our own personnel at minimal cost.

Now just before going into detail on the costs of building and operating our system, I'd like to mention the socio-economic study, which studies the economic impact and the social impact of the system on our local community. This study was undertaken by Bauer Engineering and currently is being continued by Keifer and Associates. This work is scheduled for completion in 1977 and will not be discussed further at this meeting.

Table 7 shows a construction cost summary. The whole system cost approximately $44 million, which is equivalent to a development cost of about $1 per gallon of wastewater treatment capacity. These costs included expenditures for collection and transmission.

We have also determined how much each phase of the treatment system costs. These direct costs are shown in Table 8. These do not include costs of transmission of the wastewater from downtown here to the site and also do not include the cost of drainage pumping. The aeration pumps cost about $216,000 to operate last year, the storage lagoons approximately $62,000, and the irrigation circles about $250,000.

Table 9 shows the estimated 1975 budget presented to the County Board of Public Works in January 1975 to estimate the users' rate. As you see, the total operational cost was estimated at $2.2 million. Deducting the revenue expected from sales of crops and from EPA for the Research and Development project, this cost was reduced to about $1.45 million (Table 10). Additional components of the user charge are shown in Table 11 and the actual 1975 user charge was $220 per million gallons treated. The very important thing to note in these calculations is the very significant reduction in operating costs resulting from the sale of crops which in fact helped renovate the wastewater. As a result, tertiary treatment of wastewater is being achieved at very low dollar and resource cost.

In concluding my discussion, this year has been very good for us. Past experiences have taught us how to manage and operate this system efficiently and economically. Research development, and monitoring programs have been very valuable to us in achieving these results. As I mentioned before, we have developed a very effective system of nitrogen application with a few pounds being applied each day by fertigation. This has cut out considerable needs for equipment and labor which previously were required to add these materials directly onto the land. We have learned to save energy by less aeration, balanced by greater BOD reduction through the natural storage process. We hope that we can learn more about utili-

TABLE 7.

DEVELOPMENT COSTS FOR MUSKEGON WASTEWATER SYSTEM*

Component	Millions of dollars
Collection	$ 5.2
Transmission	6.8
Pre-Application Treatment--Aeration	3.1
Storage (5 billion gallons)	5.2
Land & Relocation	
Purchase	5.4
Relocation	1.2
Clearing	1.9
Distribution--Irrigation	4.1
Recovery--Drainage	3.7
Interest & Engineering	3.8
Other	2.3
TOTAL MUSKEGON SITE	42.7
TOTAL WHITEHALL SITE	0.8
TOTAL CAPITAL COSTS	43.5
NON-CAPITALIZED COSTS	1.0
TOTAL SYSTEM DEVELOPMENT COSTS	$44.5

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* Muskegon County paid $16 million of the development costs, the State of Michigan $8.4 million, and U.S. EPA $20.1 million. The county issued $16 million worth of bonds to cover its needed capital outlay. The 1975 bond repayment was $1.2 million ($0.3 million capital and $0.9 million interest). Final repayment is due in 1997. Land acquisition costs were not eligible for federal funding at the time the grant was awarded, however, relocation allowances were. Approximately 190 families and 4 businesses were relocated.

TABLE 8.

FORECAST OF TOTAL PROCESSING REMOVAL COSTS

	Aeration Cells	Storage Lagoons	Irrigation Circles
Salaries & Fringe	$ 1,371	$ 7,324	$ 54,192
Public Utilities	157,890	-	114,140
Other	1,190	30,480	12,720
Subtotal	160,451	37,804	181,052
Laboratory	36,005	18,002	36,005
Administration	17,106	5,830	32,835
Total	$213,562	$61,636	$ 249,892

TABLE 9.

SCHEDULE OF OPERATIONAL COSTS

	1975 Budgeted Cost	1975 Forecast Cost
Direct Materials & Svcs.	$1,504,705	$ 992,017
Direct Labor	528,413	441,780
Overhead & Fringe	133,723	123,983
Administrative	110,826	150,870
	$2,277,667	$1,708,650*

* Does not include capital outlay ($106,640), amortization, depreciation, prior operating deficit or interest.

TABLE 10.

1975 USER RATE

Total O & M Cost		$2,206,460
Revenues		
Crop Sales -	$555,000 (est.)	
R & D Refund -	155,000	
Services -	35,000	
	$745,000	- 745,000
		$1,461,460

Gallonage Fee - $1,461,460 ÷
10,220 MG = $143/MG

TABLE 11.

1975 USER RATE COMPONENTS

Gallonage Fee per MG	
1975 Operating Budget	$143.00
Operating Deficit of Prior Years	8.00
1975 Depreciation (machinery & equipment only)	11.50
Working Capital Requirements	5.00
Interest on Deficit	2.50
	$170.00/MG

zing the treatment capacity of the storage lagoons, perhaps even next year going direct to the storage lagoon part of the year without any aeration of the wastewater.

We have not had any adverse problems this year. Our pipelines have been holding with only six or seven breaks this year compared with over 100 last year. We have had few problems with electrical cables as compared with last year and our dike repair problems have been minor. As you will see tomorrow, we are having a very good crop yield, perhaps double that which we obtained in 1974. Thank you.

Q. How much problem have you had with accumulation of solids in the storage lagoons? Is it a relatively small problem compared with that in the aeration cells?

R. (Dr. Demirjian) No question about that, but we are generating 62,200 pounds of suspended solids per day of which 32,000 pounds per day are going into the storage lagoons. In the storage lagoons there is a delta formation of solids which is formed around the entry of the flow into the storage lagoon. This varies in depth of about a foot near the influent pipe to less than 1/2 inch about 50 yards away. As you go further out, you barely see any solids accumulated there as yet. From our calculations based on the amounts of solids present, we expect at least 15 to 20 years time to pass before we would even need to consider dredging sludge or solids out of the storage lagoons. Next season we will be draining the different aeration cells and using sludge pumps to remove the accumulated solids. We will characterize the sludge, which we then hope to apply on surrounding land.

Q. Do your operational costs, shown earlier, include any estimated costs for dredging later on?

R. (Dr. Demirjian) No, because dredging will not be required for at least 15 to 20 years. Those operational costs do, however, include dike repairs.

PROGRAM CHALLENGES

John M. Walker*

The transformation of such a large previously untried land spray irrigation system for wastewater treatment from an idea into a successful operation in only five years is a remarkable achievement. Studies on this full-scale system have shown that it has gone far in accomplishing its goals of surface water protection by diverting and purifying wastewater before discharge and cost reduction of wastewater treatment by utilizing the water and pollutants to improve land and grow food. Challenges and opportunities now exist for strengthening these studies to optimize management and system performance, to achieve effective low cost and long term wastewater renovation, and to verify that lagooning and land spraying is a viable alternative on a large scale for advanced treatment of wastewater.

A real challenge exists to adequately perform research on an operational system this large. Research and operational needs are not always in harmony, e.g., the overriding priority of treating wastewater effectively each day imposes demands on time and resources and causes operational compromises that can compete with research. Operational goals generally result in a restricted budget to yield good performance at least possible cost. While research ultimately has the same goal of providing a better way of doing something at less cost, research itself costs money and it may first of all lead to a better but more costly solution, especially during the initial phases of study. The Muskegon experience has been an excellent example of practically oriented research being used to improve operations. These practical studies must now be documented so that this and other systems can more fully benefit. Time and resources must be allotted for research, in addition to that allocated for operations, so that this documentation and expanded study and evaluation are possible.

The wastewater treatment components of the Muskegon System include aeration, storage, irrigation, crops, and soils. Management of these treatment components directly determines the ability to treat a given wastewater and in turn determines the impact of the system on surface waters and the residential, recreational, and industrial attractiveness of the area. The important need and opportunity for expanded research and evaluation of these components is indicated.

Wastewater

In Muskegon, there are two land wastewater treatment systems, similar in design with similar sandy soils, but different in size and with wastewater of different characteristics. The large Muskegon site is designed to treat 42 MGD and the small Whitehall site 1.4 MGD. The wastewater at the Muskegon site is similar in BOD content (220 vs 250 ppm) to that at Whitehall but contains about three times less total suspended solids (300 vs 1100 ppm) and total nitrogen (14 vs 40 ppm), largely as a result of different industrial sewage input. Different management (aerating, lagooning, irrigating, and/or cropping) is required to renovate wastewater with such widely differing nitrogen content, and a unique opportunity exists to establish and verify effective means of managing the renovation of these two wastewaters.

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Additional industries are being invited to join the Muskegon County wastewater system. It is important to know whether wastewaters from these chemical industries will be compatible with land treatment. Many of these liquid wastes contain organic compounds and other exotic materials that may or may not be removed by the crop-soil treatment system. Furthermore, there could be an imbalance of the nutrients, such that new equilibriums in the soil system would be established that might be unfavorable for crop growth. These possibilities need considerable study.

Sludge

The Whitehall system will generate considerable amounts of sludge. The Muskegon system will also generate some sludge. We know that many sludges, when added to sandy soils like those at Muskegon, can benefit crop growth, but that heavy metals in sludges and excessive quantities of nitrogen can cause problems. If the Muskegon County or other sludges were applied to the wastewater irrigated lands at Muskegon, either as a liquid or dewatered solid, how will the soils' and crops' ability to renovate wastewater be affected?

Aeration

Aeration requires energy. With three identical treatment cells, the effectiveness of three different aerational modes could be studied simultaneously. It is essential to know the minimum aeration necessary to adequately eliminate problems with odor and minimize health risks.

Storage

Appreciable reduction in the toxicity and problems with biological and chemical wastewater contaminants occurs in storage. These processes could be studied in the two paired 850 acre storage lagoons. Water with different levels of pretreatment could be directed into the separate lagoons as part of the study. Utilizing treatment that is possible during storage could reduce appreciably the amount of land required for spray irrigation and/or alter the rate of irrigation on land and associated cropping practices.

Irrigation, Water Hydraulic Balance, and Water Quality Balance

To date there have been no studies on irrigation circles or smaller land units at Muskegon tying together directly the degree of wastewater renovation possible with any given combination of soil; crop; and type, rate, and quantity of wastewater irrigated. While a water hydraulic modeling study by the U.S. Geological Survey may help establish a badly needed region-wide understanding of water hydraulic balance, water quality balance can only be grossly estimated from monitored water qualities and soil ionic contents at different points in the system. The degree of renovation by the crop-soil filter, compared with the amount of apparent renovation by dilution with groundwater, is unknown. Monitoring of drainage water from a given circle has not been accomplished because more than one circle is tied into each of the currently accessible drainage lines.

Crop and Soil

Different crops singularly and in combinations have markedly different abilities to utilize nutrients in soil and water and hence to renovate wastewater. It is also believed that crops at different levels of nutrient sufficiency will deplete nutrients from soil and water to different degrees. Neither of these points have been adequately documented, particularly with respect to irrigation with a given type, quantity, and rate of wastewater.

While crops like corn offer a good cash return and can be very efficient in stripping nitrogen from wastewater, the efficient stripping only occurs during about 2 months of a 6-7 month irrigation season. How can the crop-soil system be managed to remove nitrogen from the wastewater throughout the season?

Soils have differing abilities to retain materials in wastewater like organic compounds (not needed by crops) and phosphorus (added over and above the crops' needs). Techniques exist for determining the abilities of soils for retaining phosphorus, but the studies have not been adequately performed. Techniques for determining retention in soils and ultimate distribution of various organic compounds (that might have come from irrigated wastewater) by soil microorganisms and other chemical and physical reactions have not been applied to the Muskegon System.

Wildlife

There is a unique opportunity here to determine the effects of a large land treatment system on wildlife through their possible absorption and biomagnification of organic compounds, metals, and pathogenic microorganisms from wastewaters. Can hunting be managed on a system of this nature without hunters abusing or destroying parts of the irrigation system? Can the wildlife they take be eaten with safety?

Health

There also is the important need to study the effects of a system like Muskegon's on the health of people operating the site and on people adjacent to the site. It is important to know a lot more about viruses than is currently known. Is chlorination necessary during land treatment? Chlorination of secondary effluent prior to discharge during conventional treatment is marginally beneficial and possibly harmful. If there is no chlorination of wastewater prior to its application on land, appreciable savings in cost will result. Likewise, if only minimal size buffer strips of land are required to minimize contact with the land treatment site, then again appreciable cost savings can be realized.

How safe for consumption from a microbiological, heavy metal, and exotic organic standpoint are foods produced with irrigated wastewater? Must foods be grown for consumption initially only by animals other than humans? Can vegetables like peas, beans, and sweet corn (which offers even a greater potential cash return then field corn) be grown and safely be used for human food after canning and/or freezing?

Other

Opportunities also exist for identification and verification of the socioeconomic impacts of the Muskegon system. A 5-year study is underway on this important subject for EPA and Muskegon County, but will not be discussed at this conference. The factors leading to acceptance of this system by the public in Muskegon County must also be identified and documented. As you know, many other seemingly environmentally and economically desirable systems have failed due to lack of public acceptance.

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Will we meet the challenge of answering these questions? Answers to these questions depend upon the funding and talent available for solving these problems. We welcome your participation at this conference in helping us determine the need and methods of evaluating this system, and we will welcome your participation in the future with the evaluation of this system. Thank you.

SOIL MONITORING - MICHIGAN STATE UNIVERSITY

Boyd G. Ellis*

This paper will summarize the research accomplished to date on soil monitoring at the Muskegon Wastewater Treatment site. But before discussing this phase of the work I would like to list some other studies that have been conducted at Michigan State University which may be of importance even though they were not funded by this project. Research, discussed in the following four theses, were either conducted using soils from Muskegon or are directly related to land treatment of wastewater:

1. Srisen, Manoowetaya. 1974. Adsorption ofPhosphorus by Five Michigan Soils under Anaerobic Conditions. PhD Thesis. Michigan State University.
2. Traynor, Mary Frances. 1974. Effects Upon Growth and Nutrient Composition of Corn (Zea Mays) Plants Grown on Two Different Textured Michigan Soils Contaminated with Nickel and Cadmium. M.S. Thesis. Michigan State University.
3. Schueneman, Thomas Joseph. 1974. Plant Response to and Soil Immobilization of Increasing Levels of Zn^{+2} and Cr^{+3} Applied to a Catena of Sandy Soils. PhD Thesis. Michigan State University.
4. Shah, D. B. 1975. Removal of P and N from Waste Water Spray Irrigation of Land. PhD Thesis. Michigan State University.

The first thesis is a discussion and study of the effect of anaerobic conditions on ability of soils to adsorb phosphorus. Hopefully, the soils on the Muskegon site will not become anaerobic; however, some changes in their ability to adsorb phosphorus will occur if they do. The next two theses concern the effects of heavy metals on crop quality and yield. Although the sludge produced at Muskegon is expected to be low in heavy metals, the sludge at Whitehall may be sufficiently high in Cr to be troublesome if applied to land. The fourth thesis develops, through methods of systems science combined with soil chemistry, models describing the adsorption and movement of phosphorus and nitrogen in soils. The phos phorus model is functional and can be used to predict the life of land treatment systems for given phosphorus inputs.

There are many facets to a waste treatment system such as the one at Muskegon. As pointed out in Figure 1, the land irrigation system is one portion of the total system. It must be viewed as a component of the treatment system and not just as an agricultural production system. The success of this portion of

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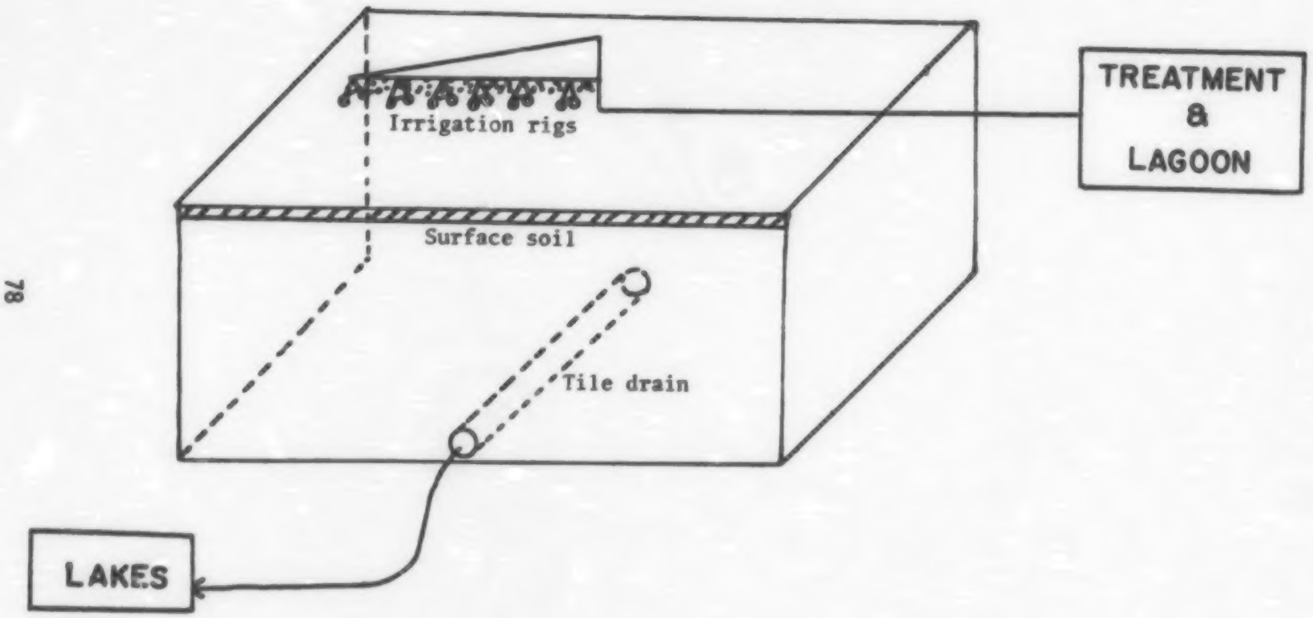
Irrigation rigs
TREATMENT
&
LAGOON
Surface soil
Tile drain
LAKES

Figure 1. Diagram of how land treatment is a part of a waste treatment system.

the system is dependent upon the soil chemistry, physical properties, biochemical reactions and living organisms. By monitoring these processes in the soil, it is hoped that we can learn how the system is working. This monitoring also permits evaluation of the success of the soil portion of the treatment system and serves as an early warning, should portions of the system become overloaded.

The following areas have been studied in the soil monitoring phase:

Table 1. SCOPE OF MSU WORK

Soil Nutrient Monitoring

Total - C, N, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, Pb, Hg

"Available" - NH_4, NO_3, P, K, Ca, Mg, Na, Fe, Mn, Zn, Cu, Pb, Hg, pH

Physical Properties

Infiltration Rate
Mechanical Composition
Water Characteristics
Bulk Density
Pore Space

Pesticide and Organic Analysis

Herbicides, Insecticides and Industrial Organics
(20 chemicals) in Wastewaters, Soils and Site Drainage

Microbiological and Insecticides

Before going further, I would like to point out to my soils friends that we do have four different major soil types that will appear in tables later. They range from a Rubicon sand, which is a very sandy, well-drained soil, to the Granby sand, which before the site was constructed had a high water table. The properties of these two soils are quite different.

What happens in the soil of a land treatment system is a reflection in part of the wastewater and its constituents applied. Table 2 was calculated from data on the constituents present in irrigated wastewater. I borrowed this data from the County to reflect how the amount of wastewater added to the soil governs in part the ability of soil to adequately provide renovation. I selected a base point after 8 inches of effluent have been applied to the different soils for comparison purposes. During that eight inches, the estimate is that about 8 pounds of nitrogen, about three pounds of total phosphorus, 20 pounds of potassium, 111 pounds of calcium, 30 pounds of magnesium, and 260 pounds of sodium were applied per acre. If we calculate from this, the quantity in 60 inches of effluent (maybe a year's application), we are getting about 60 pounds of total N, 23 pounds of total phosphorus and about 2000 pounds of sodium.

Table 2. Estimated Loading in 8 and 60 Inches of Effluent[1]

Parameter	Quantity in Effluent	
	8 inches	60 inches
	lbs/acre	
Total N	8.2	62
Total P	3.1	23
K	20	150
Ca	111	830
Mg	30	225
Na	260	1950

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[1] Data from Muskegon County.

Table 3. Nitrate and ammonium content of soils as influenced by application of eight inches of wastewater.

Soil Type	Depth	NH_4 Bg[1]	NH_4 A8"[2]	NO_3 Bg[1]	NO_3 A8"[2]
	inches	ppm			
Rubicon	0-6	5	6	3	4
	6-12	4	4	2	2
	114-120	2	2	0.8	1.4
Roscommon	0-6	10	3	6	2
	6-12	9	3	7	2
	114-120	3	0.3	1	1
Au Gres	0-6	5	4	4	6
	6-12	3	3	2	5
	114-120	2	0.3	1	2
Granby	0-6	39	3	34	8
	6-12	11	2	19	11
	114-120	1	1	1	2

[1] Bg is the background level determined by three sampling periods over two and one-half years. Each value is then an average of 8 sites times three sampling periods.

[2] A8" is for a sample collected after application of 8 inches of effluent. Each value is an average of 8 sites.

Now turning to soil nitrogen data before and after only minimal application of wastewater (Table 3, we see that the only significant thing is that both ammonium and nitrate levels are quite low, both in the Bg column (which is the background data collected over two and a half years) and in the A8" column (after 8 inches of effluent have been applied). Some change has occurred in the Granby soil. Prior to spreading effluent, the soil contained about 39 ppm ammonium and about 34 ppm nitrate in the surface. This soil type was poorly drained with a high organic matter content. Consequently, it was initially well supplied with nitrogen. The high surface nitrogen content, however, rapidly came to a new equilibrium once it was drained and operated as a wastewater renovation system. The new equilibrium was established at a much lower level of ammonium and nitrate. I suspect that some of that nitrogen must have gone down the drain during those phases of starting the system on the Granby soil.

Phosphorus and potassium data are shown in Table 4. The only thing that this table really points out is that there is no real difference between phosphorus in background, and after 8 inches of application, and 3 pounds per acre wasn't enough to cause a difference. The Granby soil appears to have lost some potassium in the surface.

Now turning to the calcium, magnesium and sodium balance, you may remember that Dr. Demirjian pointed out that this land was very low in sodium. He and I would agree that this will be short-lived. There is an exchange process going on, whereby sodium is being absorbed by the soil and calcium is either being released or in some cases it too is being absorbed. The Rubicon sand is absorbing some calcium and the Granby soil is losing calcium. (See Table 5). Sodium is accumulating in these soils and we are going to come to a new equilibrium between sodium, calcium and magnesium in a fairly short period of time. Considering the amount of sodium being applied, this will probably occur within two to three years. After this new equilibrium is reached, we are going to start losing sodium through the system, and probably the amount lost will be similar to the amount applied. This is something we have to learn to live with. We must learn to manage a crop that tolerates these levels of sodium.

Data given to you in a handout (as also given in Table 6) shows chemical change after 1 year's application of wastewater effluent. After a year's operation, the nitrate nitrogen was higher than it was initially. I think the significant thing to point out is that as you look down in the profile, you can see that nitrogen has, in fact, moved. For example, at the 30 to 36 inch depth and the 90 to 96 inch depth the background level of nitrate nitrogen was 0.6 ppm and after approximately one year's application of wastewater the level was 6.2 ppm nitrogen, certainly a significant increase. It is important that this significant increase was at the 90 to 96 depth. These samples were taken in June, and remember that effluent was applied without a crop growing. This means that we have to learn to manage and balance the amount of nitrogen applied with crop and soil conditions to get adequate nitrate removal.

I would also like to point out in Table 6 that there really was no significant change in the phosphorus after one year of effluent application, even though crops were not present. As long as the phosphorus content in the sprayed waste-

Table 4. Phosphorus and potassium content of soils as influenced by application of eight inches of wastewater.

Soil Type	Depth	P Bg[1]	P A8"[2]	K Bg[1]	K A8"[2]
	inches		ppm		
Rubicon	0-6	26	28	21	32
	6-12	24	23	13	21
	114-120	11	16	5	6
Roscommon	0-6	10	15	33	25
	6-12	8	11	17	19
	114-120	8	7	6	8
Au Gres	0-6	11	18	32	33
	6-12	7	9	21	16
	114-120	9	11	7	6
Granby	0-6	18	28	84	57
	6-12	8	16	37	37
	114-120	6	9	6	8

[1] Bg is the background level determined by three sampling periods over two and one-half years. Each value is then an average of 8 sites times three sampling periods.

[2] A8" is for a sample collected after application of 8 inches of effluent. Each value is an average of 8 sites.

Table 5. Exchangeable base content of soils as influenced by application of eight inches of wastewater.

Soil Type	Depth	Ca Bg[1]	Ca A8"[2]	Mg Bg[1]	Mg A8"[2]	Na Bg[1]	Na A8"[2]
	inches			ppm			
Rubicon	0-6	82	137	8	18	11	20
	6-12	47	84	5	15	9	11
	114-120	73	68	6	11	9	6
Roscommon	0-6	419	300	78	45	11	30
	6-12	237	340	44	43	9	22
	114-120	129	196	24	26	10	12
Au Gres	0-6	310	408	49	40	15	37
	6-12	209	233	37	22	13	14
	114-120	175	283	16	17	9	8
Granby	0-6	1968	943	208	135	21	88
	6-12	1918	942	186	132	21	50
	114-120	343	578	100	47	7	13

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[1] Bg is the background level determined by three sampling periods over two and one-half years. Each value is then an average of 8 sites times three sampling periods.

[2] A8" is for a sample collected after application of 8 inches of effluent. Each value is an average of 8 sites.

Table 6. Nitrate and phosphorus content of circle 5 soil after one year's application of wastewater.

RUBICON

Depth	NO_3-N		P	
	B[1]	A[2]	B[1]	A[2]
inches		ppm		
0-6	1.7	9.6	30	23
6-12	0.8	8.6	20	17
12-18	0.7	1.5	25	22
18-24	0.6	1.3	35	33
30-36	0.6	6.3	23	30
90-96	0.6	6.0	19	18
103-114	0.6	1.3	8	18

[1] B is background which is an average of three samplings over a two and one-half year period.

[2] A is after application of wastewater for one year.

water remains low and application rates are not too high, crop removal will probably prevent excessive phosphorus buildup and movement into groundwater.

There are other things that we could point out from our soil data. We feel that we can make predictions from our knowledge of the soil systems ahead of time -- for example, about the movement of iron that Dr. Bauer discussed. I had, in fact, talked to Dr. Demirjian about this before the irrigation rigs were even put on that area. We predicted that south of Apple Avenue the Granby soil would pass iron through its profile once it was drained. The iron is moving through the profile into the drainage water because of low subsoil pH. The Granby soil will continue to lose iron for a period of time until the pH of the subsoil comes up to a level that will precipitate the iron. Just how long that will be, I don't know for sure. I haven't tried to predict this from our data, but I would suspect that it will stop within two or three years.

In closing my part of this discussion, I would like to emphasize that we have collected base-line data prior to the operation of this site. Therefore, we have a good solid core of background data with which to make comparisons and upon which to base predictions for future performance. We also have soil performance information after one year's operation. It is important that we learn to model the soil so that if a new industry would come to use the system, with the effect of doubling the phosphorus input, we could predict what this will do to the effective life of the system. I think the modelling program is on line for doing this. Coupled with the modelling program at the University of Michigan we could also predict what this would do to waterways during the operation.

And now my colleague Dr. Erickson will continue this discussion.

PROPOSED CROP WATER TREATMENT STUDIES

A. Earl Erickson*

Dr. Ellis has discussed the soil system where wastewater percolates through and undergoes various physical, chemical and biological reactions before it leaves the soil as drainage water. The system he has described, however, does not include a very important part -- the crop plant growing on the surface of the soil. The plant is a very important part of the system in that (1) it removes nutrients from the system and recycles them and (2) the sale of crops helps defray the costs of treatment. It is our belief that the crop-soil-effluent system needs study in order to optimize both of these goals.

Soils have very limited abilities to retain nitrogen. If wastewater is irrigated onto land at moderate rates (as at Muskegon) without a crop-plant that is harvested, the bulk of the nitrogen applied in the wastewater will eventually leak into the drainage water as nitrate nitrogen. With continuous wastewater application other nutrients will also eventually satisfy the capacity of the soil to sorb them and will eventually leak from the system. However, if a crop is grown and harvested nutrients are removed and recycled, better quality effluent is produced, and the life of the soil system is extended.

Yields of crops are very important as they control the amount of nitrogen removed. The first year yields of corn at the Muskegon Wastewater Facility were 28 bushels/acre which would have harvested 23 pounds/acre of nitrogen and 4.2 pounds of phosphorus. This year the projected 60 bushels yield will remove 50 pounds of nitrogen and 9 pounds of phosphorus. Sixty inches of wastewater with 4.6 ppm N and 1.7 ppm P contains 62 pounds of nitrogen and 23 pounds of phosphorus per acre. From these calculations and from the following discussions it is apparent that supplemental nitrogen will be required. Not all of the added nitrogen in the wastewater will be available to crops, since it is applied but not retained in the soil during much of the season when crops are not present or too small to adequately use the amounts being applied. The phosphorus present in the 60-inch application of wastewater would be sufficient phosphorus for a yield of 150 bushels/acre.

As mentioned above, harvesting nitrogen with a corn crop alone has the complication that the corn plant harvests most of its nitrogen in six or seven weeks in July and August, while wastewater is applied over 35 weeks. Over twenty weeks of wastewater nitrogen is free to leach from the soil. A possible solution to this would be to grow a cover-crop which will harvest the nitrogen during the other part of the year and release the nitrogen to the corn when it it required. This could have the two-fold effect of better wastewater renovation and less nitrogen fertilizer required for the corn. An example of such a system would be a one-year rotation of corn-rye. Rye would be planted in the corn in August. It would remove nutrients during the Fall and Spring. Corn would be no-till planted in the herbicide killed rye in May. The rye would release its nutrients into the system through the summer and the cycle would be repeated.

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There may be other cover-crops that would be better than rye. There may be better crops than corn. Alfalfa might do better in polishing the effluent. There are many of these sorts of questions which must be answered in order to develop a cropping system which will optimize nutrient removal. The Muskegon Wastewater Facility is where these answers are needed and where they should be found.

There will also be sludges to be disposed of at Muskegon. The question is whether they can be disposed of on the sandy soil of the facility with the high water application without contaminating the environment. This should also be researched.

We are proposing a new research project to find these answers. The research variables to be studied would include high and low nutrient wastewaters as found at Whitehall and Muskegon respectively, different types of the sandy soils on the project, different cash crops, different cover crops and different cropping systems. The proposal will require the establishment of a research farm with larger than the usual agronomic plots so that percolating water and drainage water can be isolated and released to the individually treated plots. The soils would be sampled with depth and time and the water would be sampled during the year with suction lysimeters and/or shallow wells. In this way the various crop-soil-effluent systems will be evaluated. These evaluations would allow the development of systems which would optimize the treatment of wastewater and production of crops and answer the questions regarding disposal and recycling nutrients from sludge.

Q. What problem do you expect with heavy metal accumulation in soils, leaching through soils, and uptake by crops?

R. (Boyd Ellis) Background levels of heavy metals at the Muskegon site are very low. Heavy metals coming to the site in the wastewater are also very low in concentration. We would expect that any heavy metals added to the soils in the wastewater will be readily absorbed in the surface layers. We expect and would predict very little leakage of heavy metals through the system. Iron is an exception, because it obviously leaches from subsoils that are quite acid. This is not iron being applied in the wastewater, rather it is iron that is native to the soil. Iron leaks out because of a low soil pH. This problem should correct itself in a few years.

The only other heavy metal of possible concern is chromium at the Whitehall site. Chromium there arises from tannery wastewater. In some early studies we applied a soluble chromium (Cr^{+3}) to soil from the Muskegon site. This form of chromium was very toxic to crop growth. In fact, we could kill most plants when we reached 400 ppm in the soil. There are some studies where sewage sludges have been applied to soils which are high in chromium. In these studies it took a much greater addition than 400 ppm to be toxic to plants. While there is some reason for concern about chromium, most studies elsewhere have not shown it to be much of a problem. Furthermore in our studies we found that high chromium killed the plant, and hence there was no edible portion containing chromium. I therefore don't think it is much of a health hazard from that standpoint. While some additional study of this potential problem might be desirable, I understand that much of the chromium in the wastewater from the tannery is now being recovered before discharge. The potential for a problem with chromium, therefore, is lessened accordingly.

Q: Do heavy metals at Muskegon pose a threat to the food chain?

R: (Boyd Ellis) Dr. Knezek is the expert on heavy metals in our Department and I am sure he will correct me if I get out of line. There are certain heavy metals that we are concerned about in the food chain. We are concerned perhaps first and foremost about cadmium. As far as I know, cadmium is very low in the incoming effluent here, and so for this specific site cadmium should not be a problem. I would caution, however, against generalizing this to other sites, because cadmium is something that you must monitor and understand in each specific site. If it is high, you cannot tolerate cadmium in the food chain.

Other metals are of much less concern in the food chain. Zinc can be tolerated at moderately high levels and in fact is often lacking in the diet. Copper also can be tolerated in the food chain up to moderate levels. While nickel can be more of a problem than copper or zinc, its levels are quite low in both of the Muskegon and Whitehall systems. Chromium should not be a problem in the food chain because its level in the wastewater has been reduced and it is not in a form readily available to crops. If it were available and present in large quantity in the soil, the plant would be killed before the levels of chromium within it became excessive.

Q: Are there other materials in the wastewater that can pose a hazard to the environment?

R: (Boyd Ellis) I mentioned just in passing that we are analyzing for more than twenty organics, including herbicides, insecticides, and industrial organics. Dr. Wolcott is the expert in this field and Art will also correct me if I am wrong. The background levels of these materials were extremely low on the site. The only compounds that were detected were dieldrin and DDT species, in very low quantities and in one of the sandy soils. There are a few organics coming to the site in the wastewater occasionally at high levels. These materials may also be detected leaving the site, particularly when wastewater has been applied in large quantities over a short time period. We really do not know the potential harm arising from these organics which may move through the system. There is some indication that there is an increasing ability of the storage lagoons and soils to degrade these organics. Where the levels of some organics being monitored are in the parts per trillion range it is very difficult to know the validity of the results. We recommend additional study.

Q: How much of the program that you talked about is actually funded and on-going? How much of it is proposed that you would like to get funded?

R: (Boyd Ellis) Everything that I talked about is and has been funded and on-going. All of this work has been funded in part by EPA except for the four cooperative studies that I mentioned by different graduate students. These were carried out at Michigan State University under various other funding arrangements. The soil monitoring program will terminate, unless extended, as of December 31st this year. Any research beyond that date would come under proposed new funding.

We are proposing to continue the monitoring with some change in the approach. We believe that certain analyses can be reduced and that certain new approaches in the monitoring program can be more effective in determining the changes in the soil brought about by the addition of wastewater. The program that Dr. Erickson spoke about is largely new proposed research. This important research largely hinges around learning how to manage nitrogen, wastewater application, and cropping most effectively to optimize yield and renovate the wastewater.

LAKE MONITORING - UNIVERSITY OF MICHIGAN

John M. Armstrong*

Thank you, Steve. It is a pleasure to be here again in Muskegon County. We have come here quite often in carrying out our monitoring program. We have prepared a handout that is available in the lobby to all of you. There should be enough for everybody in this room. Essentially the handout describes the highlights of our project to date. A page or two also talks about what we propose to do in the future as Boyd Ellis has done for Michigan State. I am not going to show you reams of data on slides, rather I am going to describe very quickly where we are.

As Steve pointed out, our project deals mainly with the impact of the discharge from the wastewater system on the aquatic environment. What changes have or will occur in the aquatic environment because of the new wastewater system are the things we would like to determine. Our purpose is not to evaluate the wastewater treatment system itself; although if one used it correctly, an evaluation could be done since the lakes and the streams themselves are a part of the new systems and do indeed reflect the effectiveness of the plant. Rather, our purpose is to examine and determine the impact that the wastewater system will have through its discharge on the aquatic environment. So the major emphasis is to look at the surface waters in the County.

Before I go on, I would like to say that I have two of my colleagues with me: Professor Raymond Canale, who is also going to speak at this conference, and Dr. Peter Meier from the School of Public Health. A large number of persons have been involved in this project.

We have been under contract from the Water Resources Commission since May of 1972 to carry out a series of system monitoring efforts. We have been conducting a number of various studies during the course of the project which ends in December of this year. In this period we have been sampling some 24 stations in the three major drainage basins that have been impacted or affected or might be affected by the Muskegon County Wastewater Management System. We sample on the average of twice monthly. We sample all year round, twice a month at these 24 stations. The bulk of them are on the three lakes - Muskegon, Mona, and White. We also sample the streams that run through the site and discharge into the three lakes.

The results of our limnological monitoring program have permitted what we think is a very complete evaluation of the water quality in the lakes over the three-year period. This program has shown that prior to diversion, all three lakes were eutrophic, still are, and highly so. All the lakes become stratified during the summer and experience extensive periods when the hypolimnion of the waters are devoid of oxygen.

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Because the diversion of wastes from the previous discharge points to the new land treatment site began only recently, there is nothing solid to prove about the effect of the system. So we really look at 1975 as the first year of sampling in which the treatment system was in some normal model of operation.

Our sampling operations were conducted primarily from boats. In addition we are making some aerial surveys of aquatic weeds. Professor Canale will talk more about this.

All three lakes are high in all the nutrients, which result in frequent summer blooms in the green and blue-green algae. We have run some intensive bioassays that Professor Canale is going to talk about which indicate that during the spring and fall the algae in White Lake are phosphorus limited and in the summer they are nitrogen limited. Our studies on phytoplankton have revealed no major changes in species in any of the lakes and no major changes in any of the organisms that we have been identifying and following. The dominance of some of those algal species that we have looked at have indicated, of course, a high and advanced state of eutrophication. As I stated previously there were no statistically significant changes noted during the course of the three year monitoring program, which is not surprising considering the size and the volume of these lakes and the very short time that diversion has been underway, e.g., diversion of waste to the wastewater treatment site.

In addition to the routine monitoring that we carried out on the lakes, we have done some special studies to determine how the wastewater system might influence the distribution of aquatic macrophytes and how the presence of macrophytes might affect recovery of the lakes. It is not clear yet what impact the nutrient diversion or the waste diversion program will have on the distribution of macrophytes in the lake because of their abilities to absorb nutrients directly from previously nutrient and pollutant rich sediments. Furthermore, distribution of these macrophytes is also affected by the depth of water in the lake and the turbidity of overlying waters. Professor Canale will talk a little bit more about the macrophyte experiments.

We have also investigated the interaction between the sediments and the overlying waters, looked at establishing profiles of phosphorus, ammonium chloride, iron, and other chemical species to determine how these interactions might affect recovery of the lakes. This work has primarily been carried out in White Lake. In these studies we found that the overlying waters are very low in oxygen during certain periods of the year. Coupled with other findings this suggests significant upward transport of nutrients by diffusion. As you know lake sediments can absorb oxygen and release phosphorus at very high rates. In some experiments that we have done, the rate of oxygen uptake observed for White Lake was enough to deplete all of the oxygen from the hypolimnion in about 16 days. We are just beginning to understand these important sediment interactions and we need to continue these process experiments.

In addition to our limnological monitoring and special studies, we have been developing mathematical modeling techniques for processes occuring in the lakes. The model will take into account the changes in material balance on the lake from the diversion and existing biological processes. By modeling we hope to predict what might be expected in terms of effects and performance of these three lakes as a result of the diversion. We believe that we have made significant progress in development of the model, that we now have an excellent understanding of the lakes, and that we are now in a good position to begin the evaluation phase of the program. We have submitted a three-year proposal to the DNR and to the EPA for possible continuation of this work.

We have conducted what is, in the textbook sense, a classical limnologic quality survey of the region. We are now ready to examine more closely and begin to measure through a continued monitoring program, some of the changes that are going to result from the continued and hopefully permanent diversion of wastes through the new system. We feel that we have completed the first phase here and are ready to go on. Our current contract terminates in December. Our field program will probably wind down sometime in November unless there is some continuation of funding.

We propose, as a three-year effort, to essentially continue the station monitoring that we have carried out for the last three years. We are suggesting some streamlining of data collection in terms of stations. We are proposing some slightly different analytical techniques, but in essence we propose a continuance of a very basic, classic monitoring program, i.e., we have learned some things about how to do essentially the same program a little better. The lake modeling work will continue under the present format. We are going to refine and "tune" the models and make more accurate estimates as time goes on as to the long-term recovery times for these lakes. Of course, the ultimate objective is to be able to make some predictions or have a better understanding about this concept in general as it applies to the water quality concerns of lakes that receive substantial discharge of wastes.

We have also proposed a look at the waste treatment system itself - to look at it as a system and to begin building some type of a materials balance through the entire system. I think this would be closely tied to what the Michigan State people have gotten into. Perhaps this would result in the development of a computer simulation model of the waste treatment system and an examination of some of the optimal strategies that might be used to operate the lagoons and the farming operations with respect to the different objectives. There is one major objective, that is to meet the water quality standards and to preserve the quality of the aquatic environment. There are some other objectives like maximizing the profit from the crops that are important. There are some interesting studies that we have proposed in our program that would tie in nicely to the examination of the objectives.

So, that is very quickly where we are, and where we would like to go. We have some findings that now indicate some of the nutrient limiting conditions that seem to exist. We need to look at those conditions very thoroughly in the next three years. It is my feeling that three years is probably the very minimum amount of time that one can spend in continuing monitoring to obtain any feel of the impact that this large system will have on the three lakes and their aquatic communities. We are talking about a system that changes very, very slowly, at least in the initial time period. I think that in order to establish those rates of change, we need to continue to look as closely as we have been.

I would like to turn it over to Professor Canale.

MODELLING STUDIES - UNIVERSITY OF MICHIGAN

Raymond P. Canale*

As has been mentioned earlier the purpose of our project is to evaluate the impact of the irrigation system on the surface waters of the county. To determine this impact we have established sampling stations upstream and downstream from the point of discharge of the spray site and on the lakes which we monitor routinely.

I would like to tell you something about the characteristics of the three lakes in Muskegon County which are affected by the Wastewater System. They are all eutrophic. They all experience depleted oxygen conditions in the summertime in the bottom waters. Very high water concentrations of both phosphorus and nitrogen were measured in lakes during some parts of the year in 1973 and 1974. At other times contents were lower. When you consider the amount of nutrients that algae and other aquatic plants require, you can estimate that Mona Lake would be phosphorus limited and Muskegon Lake would be nitrogen limited. White Lake is on the borderline, maybe nitrogen, maybe phosphorus limited. Some of our laboratory work has demonstrated that nitrogen limits the aquatic plants in the summertime in White Lake and phosphorus limits them in the fall and spring. The typical summer chlorophyll values found are extremely high, being approximately the same as what you might expect in the western basin of Lake Erie. The productivity rates are again quite high.

Our chief new interest, of course, is the 1975 data. Concentrating on White Lake, we have had nearly a full year diversion of wastewater by the system at Whitehall. Thus far we have gone over data obtained up until late May. There is very little indication at this point that we have substantially reduced the phosphorus going to that lake. We need to decide now whether the phosphorus coming into the lake is from the spray site or whether it is from other nonpoint sources upstream of the treatment site.

As we begin to receive more of the data, which we have obtained up until now (September), we will be able to compare nutrient balances. These balances will be of data obtained on the site, where the spray discharge enters the river and at upstream and downstream points. Until we make these more detailed comparisons, our conclusions presented at this meeting must be considered as preliminary.

Some preliminary data on the other lakes indicate more or less the same kind of behavior. Nitrogen in 1975 appeared to be higher than in 1973 and 1974. We are again not sure why. what we are sure of is that we just haven't had enough time to document convincing changes in either the streams or the lakes in relation to the treatment system.

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As has been mentioned earlier, aquatic macrophytes are a definite problem. These macrophytes interfere markedly with recreational activity, such as swimming, fishing, and boating. Our scuba divers have harvested these macrophytes in order to determine their biomass and establish more fully their surface area which covers about 20% of White Lake.

These macrophytes obtain their nutrients largely from the sediment and are limited by light in the lake. Stretching our imagination, you might imagine that the treatment system might reduce nutrients in the water and decrease phytoplankton. The turbidity would thereby be reduced whereby the light available to the macrophytes would be increased. This might increase the macrophyte problem in the lake because the macrophytes feed on nutrient rich sediments which react much more slowly to nutrient diversion.

The macrophyte survey was done in 1974. Water was high that year, and, of course, there is a possibility that low water conditions would make the situation even more serious.

I think that it is important that we continue to study the nutrient requirements of the algae and macrophytes in White Lake, both from water and from sediments. The extent that macrophytes are limited by light should be established on a quantitative basis, so we will be able to determine what is going to happen in regard to macrophyte population.

I wish to say a bit more about the lake bottom sediments. These sediments contain high concentrations of nutrients. Concentrations of ammonia and phosphorus dissolved in the sediment are always an order of magnitude higher than in the overlying waters. We expect that both these nutrients will be released from the sediments by diffusion (stimulating growth of algae) and by absorption by macrophytes.

Simultaneously with nutrient interactions, sediments also deplete oxygen from the bottom waters of the lake. Rates of oxygen uptake, as measured in our experiments, show that the sediments have the potential to deplete highly oxygenated lake waters in a matter of a few days creating objectionably anaerobic conditions.

It is important to continue to quantify the amount of sediment in the lakes and the release rate of nutrients from the bottom sediments to tell how long the processes are going to delay recovery of the lakes after wastewater nutrient diversion and to predict the extent recovery will actually occur.

We have made progress in making these kinds of predictions using a model of the system. The model contains chemical and biological components. We have applied our model first of all to White Lake where we have a more complete understanding of diffuse and point source nutrient inputs and where our definition of the existing biological and chemical situation is most advanced. We have come up with estimates for algae productivity as a function of nutrient concentration, light and temperature. We have come up with models for evaluating the amount of exchange between the hypolimnion and the epilimnion, the top waters and the bottom waters. We need to evaluate the release rates and the potential for nutrients in the sediments.

Our next step will be to synthesize these submodels into a comprehensive picture and to verify this model. If that is possible we should be able to evaluate alternative restorative actions which might be required. For example, it may be necessary to dredge the sediments if we are going to get full utility of these waters. It might be necessary to aerate the hypolimnion in order to control the effects of the sediments. I believe this kind of model will give us the predictive capability for assessing the need for doing these kinds of additional measures.

Perhaps I can indicate more clearly how the model and associated experiments, e.g., on sediment interactions, will help us gain an understanding of what is going on in the lakes and the desired predictive capacity. I will take the example of observed phosphorus in White Lake in 1974 as compared with simply calculated phosphorus levels based on tributary loadings alone. On this basis the model adequately predicts phosphorus levels in the beginning of the year but the prediction becomes progressively worse in the epilimnion and particularly the hypolimnion later in the year. In the late summer there is an increase of about 20 mg P/l over and above that which can be accounted for based on loadings.

Part of the explanation is that phosphorus is being absorbed by the algae in the epilimnion and then sinks with the algae into the hypolimnion as the season progresses. Another part of the explanation lies in the fact that phosphorus is being released by bottom sediments. We have been able to substantiate this through the kinds of research that has taken place in our laboratory.

I think that these kinds of experiments, coupled with our modeling, will eventually give us the capability to predict what kinds of lakes are going to be most responsive to nutrient control, what the extent of recovery might be, the rate of recovery, and finally to predict any other restorative measures in addition to wastewater diversion which might be required.

I will be happy to answer any questions now that I can. I guess John is also open for some questions. Are there any questions?

Q. Would these proposed experiments be more valuable to us in eight or ten years than now?

R. It would be best if we could conduct the studies for the next 20 years. It turns out that the actual documentation of recovery of lakes, following any kind of control measures, is extremely limited. We just don't have information on the recovery of lakes following some kind of treatment system. However, I think if you skip taking measurements for ten years, you've got to lose the continuity that you require. You are going to lose the continuity in that the levels of the lakes change along with changes in other confounding factors that we can't anticipate right now. I think you really need that continuity to do the job.

Q. Do you think the lakes will really change very rapidly?

R. I don't think you will see rapid change with sediments, but I think it is an open question as to whether these sediments are going to delay recovery or not. Taking a simplified approach, the washout rates or exchange of water in White Lake at least occurs about seven or eight times a year. From that kind of analysis, you would expect very rapid response and you haven't seen it. Perhaps therefore the sediments are delaying changes in water quality after wastewater nutrient diversion.

Q. Are aquatic macrophytes in any way helpful?

R. A variety of fish use macrophytes as a refuge from predation and that would be one of the main beneficial uses. On the other hand there are tremendous obvious damages to sailboating, motorboating, swimming and other recreational activities, so in my judgment they would represent a net negative impact.

SURFACE WATER STUDIES AND ROLE OF MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Paul Blakeslee*

The Muskegon County Project originated at a time when primary responsibility for program review rested within the Municipal Wastewater Division of the Michigan Department of Public Health. In 1973, our Division was transferred to the Department of Natural Resources. Through the review period and continuing today, we have tried to take a balanced look at both the environmental and natural resources effects, and health effects of wastewater related projects. The review of the Muskegon County Project at the time of project development was truly a team effort. You heard much discussion this morning about the people that played major roles in the initiation of the project, there were also many, many people that played major roles in the review activity.

I noticed an EPA booklet on the table in the lobby this morning, and we have copies back in the office, which dealt with Evaluation of Land Application Systems. Many of the people that were involved in preparation of that document were also involved in the review of this facility and many of the concepts that have been incorporated in the Muskegon Project are now being incorporated in other facility designs.

Part of obtaining the right answer to any problem is learning what questions need to be asked. Back in 1969 and '70, we learned an awful lot about questions. We are here today talking about some of the answers to questions that we will still be looking for in 1975, '76, and '77. We hope that the overall objective of this conference, to stimulate documentation and further investigations to obtain these answers, will be achieved.

One of the key elements in our initial involvement in the project as a review agent and the really primary perspective from which we looked at the project was that it is the wastewater treatment facility for the entire Muskegon Metro area. It is also a large farm operation. It is also a research facility. But, from day 1, we have to expect it to perform as the wastewater treatment system for the community. We have to balance this fact, on a continuing basis, with many of the other possibilities for use of the system. Examples of potential conflict include multiple site use, cropping for economic return versus optimization of performance, even operation of system components under stress conditions for research purposes. These all have to be balanced against an overriding perspective, from our point of view, that this is the wastewater system to serve the community.

One of those key elements was avoidance of ground water impact off-site. The facility was designed and is operated in essence to provide inward migration of ground waters so we are not affecting off-site individual's uses of potable water supplies. The monitoring network, that was installed and is in use today, is intended to assure that that concept is fulfilled in the day-to-day operation of the system.

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A part of this concern, with regard to groundwater impact and health related impacts, led to decisions to exlude residences from the project area, rather than permitting an intermix. It will be necessary to take a much more detailed look at some of the judgments that were made before we can reverse any of those kinds of decisions, e.g. to permit direct use of privately owned lands for wastewater renovation.

We similarly have concern in some areas with regard to exposure of a generally unsuspecting public to a wastewater facility such as the Muskegon facility. We recognize that we have created a man-made environment here which has many potential uses. We're wanting to look at concrete proposals for these uses to make sure that they are well founded and properly controlled. We do not want to permit greater public access without a good hard look to start with.

The selection of wastewater application methods and site isolation criteria were considered with respect to potential movement of aerosolized wastewater particles off-site during irrigation. Downward directed low pressure spray application methods were developed which have helped minimize aerosol formation and droplet migration off-site. I am sure there is much more that can be done to look at both the effectiveness of the system that has been developed here and also at alternative methods of application, some of which require less energy. DNR has a keen interest in the results of these ongoing research studies.

I did not come prepared to talk in much detail about DNR's part of the three-way research project involving Michigan State University, the University of Michigan and ourselves. Our involvement somewhat parallels the work done by the University of Michigan in looking at the impact of the system on the streams and lakes downstream from the site.

In addition to learning about the impact of the system on the surface waters from our studies and those of the University of Michigan, we want to know many of the things that Dr. Ellis and Dr. Erickson were discussing here in terms of the actual project itself. Can the anticipated high levels of performance of the crop-soil filter be sustained? Over what time period can we achieve these results? What can we do to optimize? What can we do to extend useful life of the system?

These are all things that each of us involved with wastewater treatment need answers to, whether as treatment authorities, regulators, researchers, or other people involved in developing these kinds of concepts. What are the costs of each of these kinds of improvements in the technology? What do we give up in terms of resources? What do we gain in terms of resources? What is the overall balance? Only the continuing study of what we are seeking here today is going to give us those answers.

I must throw out another word of caution here. There is a risk involved in the wholesale translation of concepts from one research environment to another. I think you all recognize this. It can lead to disaster when information is picked up at one site and plugged in at another site without asking some of the real searching questions.

One painful example comes to mind. A Michigan community decided to install a land application for wastewater treatment to protect a highly eutrophic downstream lake. This facility was constructed in essence to utilize the living filter concept. Based on another system, it was assumed that the soils at the new facility would be sufficiently permeable to accept large quantities of wastewater. Unfortunately it readily became apparent in 1974, the first year of operation, that the soils were not very permeable, and the lake in essence received inadequately filtered raw sewage wastewater. Someone had picked up information, plugged it in at another location, and forgot to ask the necessary searching questions, in this case about soil permeability. That community bought and paid for a system they hoped would work. It isn't quite the same success story that we are seeing here. It's those kinds of concerns that we are involved in as a review agency.

Going beyond the research and review aspects, we are involved in a day-today, month-to-month ongoing operation of wastewater treatment facilities. We are attempting to work with the Muskegon project to assure that everything is moving smoothly. We receive ongoing operational performance information from the County on a month-to-month basis. We are asking the County to provide us with very detailed information because of the uniqueness of this system and our hope that we can translate experiences from here with realism to other facilities and other proposals.

I have been rather general in my comments. I will take any specific questions you might have.

HYDRAULIC MODELING - U.S. GEOLOGICAL SURVEY

William B. Fleck*

I notice that we are quite a bit behind the Lansing lunch hour and I think even behind the Chicago lunch hour; therefore, I shall be brief in describing the role of the U.S. Geological Survey, particularly that of the Water Resources Division, and our relation to the Wastewater Management System.

We are working on a cooperative project with the Michigan Department of Natural Resources, more specifically the Michigan Geological Survey. The project is funded for a period of not quite two years in length. It started early last year and will be completed, hopefully, some time early this coming year.

Hydrologically, the system that we have here is rather unique in that very little work has been done in the past on such a complete operation. We, in the Geological Survey, are particularly interested in the effect that the operation will have on the ground-water flow system; both on the regional system and on the flow within the 10,000 acres of the Muskegon Management System.

We felt that to do this best, we needed to develop a model, a digital model, that could simulate the ground-water flow complex within the area. The area is complicated because of miles and miles of under-drains that flow into ditches, then discharge to the natural drainage system.

We're thinking in terms of a small scale model that will simulate the aquifers in an area that is approximately 35 or 36 miles in length, extending from Newago and Sparta on the east to Lake Michigan on the west. After we have developed a model that somewhat accurately simulates the regional pattern, we then plan to develop models that encompass smaller areas, perhaps a few of the irrigation circles in the south, a circle or two in the north, and then to superimpose these models on the regional model.

We also have, along the way, been measuring the water levels in some 96 observation wells in the area; most of the wells were installed as part of the management system. We have installed others where we thought there was a shortage of wells.

We have also installed five stream-gaging stations to obtain data on the amount of water that is being discharged from the area -- both ground-water runoff and surface runoff into the ditches and water that is being discharged by the under-drains. In order to work the model properly, we need to know what the entire flow system is. We have developed what we believe is a reasonable model of the geometric and the hydrological parameters of the aquifers in the area.

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We are essentially talking about two principal aquifers. The water-table aquifer which underlies the area is very shallow, ranging from about 10 feet below land surface and extending to depths of perhaps 80 to 90 feel below land surface at a maximum. At much greater depths, there is a sandstone bedrock aquifer that is rarely used for water supply in the area. However, the aquifer is used extensively in much of the State, particularly in the southern part of the Lower Peninsula. We believe at this point that we have a good model of this aquifer. I was hopeful that we could have some initial answers from our study which would demonstrate what we are going to do; however, we are still having minor problems with our numerical schemes.

One of the objectives of developing a model of the area is to be able to apply stresses, such as spraying two inches, four inches, or more water on the area and then determine how much ground-water outflow there may be (or may not be, as Dr. Demirjian has suggested) from the area. Incidently, our preliminary data indicates that what he (Dr. Demirjian) said about the west side of the lagoon is, in fact, correct; there is a ground-water divide developing just to the west of the lagoon perhaps 700 feet from the seepage ditches. The principal objectives, then, are to see what happens both locally and regionally to the ground-water system.

The possible next step, although not part of the current project, would be to develop a transport model. In order to do this one needs the ground-water model to couple to a quality or transport model. Some of the work that has been done by others, such as the chemical information obtained by Michigan State University, will be used to explain what is happening to some quality parameters once effluent water reaches the ground-water flow system. This very quickly then brings us to lunch, unless there are some questions.

Q. (Question was not recorded, but evidently concerned the types of aquifers located within the area.)

R. The principal aquifer system in the area is the water-table aquifer. The gradient of the water-table is, as you would guess, principally toward Lake Michigan. Locally there is a steep gradient toward Mosquito Creek. The drift thickness is on the order of two hundred to four thousand feet over the regional area that I was talking about, 35 miles east-west by 18 miles north-south. Under the drift there is the Marshall Sandstone which is a very good aquifer in much of the State. There is some water obtained from this aquifer somewhat to the south of the wastewater site. Although the water in the Marshall Sandstone in this area is sometimes a little saline, it is nevertheless a productive aquifer. I think that it needs to be part of the total picture when we are making regional models, because some of our ground-water flow is there. For example, there is some upward movement of water from the Marshall Sandstone through the confining beds into the water-table aquifer west of the management site. So, that quickly is the picture of the aquifers. Is that what you are asking about?

Q. (Not recorded.)

R. I'll answer this question then we will adjourn for further questions after lunch. We do monitor the amount of effluent that is being discharged from the under drains or ditches to the surface ditch at the outfall. We also have a gage that monitors discharge to Black Creek, excluding what's being pumped from the seepage ditch to Black Creek. I don't have the discharge figures with me, but we have been measuring about 25 cfs from the outfall.

Q. The reason I asked the previous question is that you probably are getting a dilution of the effluent by drawing into clean water from offsite and mixing with the outflow from the site and therefore you're getting a better picture of the wastewater renovation with lower nutrient content than you might expect otherwise. In other words, you may be solving a pollutant problem by diluting it again.

OTHER CONCERNED AGENCIES

WASTE MANAGEMENT RESEARCH IN U.S. EPA

William A. Rosenkranz*

Thank you Mr. Chairman, it is a pleasure for me to visit the project again and learn of its successful performance during the current season.

During the earlier sessions we have had speakers discuss the history, design, and operation of the system, and now I would like to discuss briefly certain projects of the EPA Land Treatment Program as it relates to the Muskegon Project.

Historically, the EPA research on land application of municipal wastewater predates the Agency by a number of years. In Fiscal Year 1969, the program consisted of two in-house projects conducted by the Robert S. Kerr Environmental Research Laboratory at a funding level of $116,800. We have now completed sixteen (16) projects. In Fiscal Year 1975, the program had increased in scope to include seven (7) active in-house projects and nineteen (19) extramural projects with a total funding level of a little over $3,000,000. It is important to note however, that of this $3,000,000 (+) some $2,300,000 was obtained through supplemental funding. Current projections for Fiscal Year 1976 call for expenditures of $360,000 for in-house and $549,000 for extramural projects or a total base program of $909,000. At the projected level we can expect little more than maintaining the integrity of our existing program affording no opportunity for new starts.

For the purpose of simplification, the land application program can be discussed in four broad areas: "crop irrigation, infiltration-percolation, overland-flow and more basic research applicable to more than one category."

In spite of the long history of cropland irrigation with municipal effluents (primarily in the southwest) there is still an obvious lack of quantitative data to delineate the balance between the beneficial and adverse influence on the local environment. One group of projects places emphasis on application rates, crop responses, soil changes, and ground-water quality changes while the other (such as the Muskegon project) are designed to demonstrate crop irrigation approaches in geographic areas where historical information is scarce or non-existent.

Research and demonstration activities in the infiltration-percolation area have primarily involved the more adequate evaluation of treatment effectiveness through "better management" as opposed to the earlier practice of simply disposing of the wastewater. Projects to date have been centered largely in the water-short southwestern states although two projects have been funded in the north central region (Minnesota and Wisconsin). In addition, the first of several studies to make comprehensive evaluation of existing infiltration-percolation facilities has been started at Lake George, New York.

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Overland-flow treatment of municipal wastewater, although a newly developing technology, promises to be a viable treatment method, based on studies completed to date at the Kerr Laboratory, from other municipal systems and from industrial experience. It differs from the irrigation and infiltration-percolation methods in that the systems are designed with a planned discharge. In this sense it is more directly comparable to conventional treatment methods.

The more basic research has focused on the special aspects of phosphorus retention in soils, denitrification, biodegradation of organics and climatology. Each of these aspects are oriented toward a more rational cost-effective design practice useful over a broader geographic range.

In addition to the work described, EPA through interagency agreements, committees and informal arrangements, cooperates in a total National land treatment research and development effort. This cooperative effort is extremely important since it is an attempt to avoid duplication and to maximize research in this period of reduced monetary support.

As a result of research of numerous organizations coupled with a need for an alternative to the more conventional treatment systems for municipal wastewater, there has been an increased employment of land treatment of wastewaters in recent years. Cost-effectiveness evaluations required under the EPA Construction Grant program must include consideration of soil treatment systems. One of the primary objectives of the research and development effort is to provide the information on soil treatment systems necessary for use in cost-effectiveness evaluations required for the EPA Construction Grant projects.

Although much progress has been made in the more rational design of land treatment systems, more adequate evaluation of systems such as at Muskegon are necessary. In this manner, more cost-effective design criteria and operating modes can be developed. Additional emphasis should be placed on resolution of health related issues, odor control, long-term ecological effects, and social acceptance. The latter is important for resolution of problems associated with site selection and availability.

Thank you.

HEALTH AND ECOLOGICAL EFFECTS RESEARCH IN U.S. EPA

Roy Albert*

INTRODUCTION

I am pleased to have been invited to speak to you today on the health research program of the Environmental Protection Agency as it relates to wastewater treatment and disposal. Essentially, the Agency's program is "mission-oriented", that is, it is designed primarily to provide a scientific foundation for health-related environmental action.

Since a great deal of the effort to protect our environment ultimately pertains to protecting human health, the health effects portion of the research and development program can be viewed as a fundamental component of EPA's overall effort. Much of the Agency's authorizing legislation relates to health protection.

Health Research Programs

To provide the health intelligence required for issuing permits, guidelines and criteria, or for promulgating standards, information on exposure-dose-effect relationships is required. We also use such information to evaluate the potential health impact of options for pollution control. In promulgating standards, we want to insure that the standard is placed on the continuum and that the margin of safety is adequate, so that health is fully protected but that overly stringent or costly controls are not required.

Turning more specifically to our programs, I shall indicate the general kinds of wastewater research areas and their respective activities. The programs are a mix of both extra- and intramural work, and for the purposes of this discussion, I will not draw a distinction as such since the extramural portions are managed by the labs. Although EPA's research labs are located across the country, practically all the health labs are located in conjunction with the laboratories in Research Triangle Park, North Carolina, and in Cincinnati, Ohio.

Most of our water research labs are either located in Cincinnati or currently report to the Cincinnati laboratory. The program at present is essentially categorized as "Water Supply Research" and "Water Quality Research." Today, I will limit my remarks to "Water Quality." I might note that the total water program is large, and in this discussion I shall also limit my comments to activities specifically related to health.

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Water Quality Research

In the water quality portion of the program, our health research is directed toward developing criteria for the safe treatment and disposal of wastewaters and sludges and criteria for fresh and marine recreational waters.

A. Wastewater and Sludges

EPA's research effort on the health effects associated with wastewater and sludge is a relatively new program activity beginning only in FY-74 with funding of $200,000. In FY-75, funds had increased to about $500,000 while FY-76 funds amount to about $1,180,000 with the monies roughly split between wastewater and sludge research. The research in this area most specifically relates to your concerns with the Muskegon project. The program deals primarily with the health implications of land applications of wastewaters and sludges. It should be noted that epidemiological information on the potential health impacts of installing land treatment facilities is limited but expanding.

The disposal of sewage sludge presents potential impacts on man's health. The problems encountered include odor and the exposure to chemicals and infectious organisms inhaled via aerosols with resultant potential systemic problems and eye and dermal irritation. Aerosol inhalation results from spraying and land application of sewage and sludge and from wastewater treatment plants and can be controlled through appropriate protective measures such as landscape or vegetation screens and covers over aerosolization tanks. Infectious organisms and chemicals present in the sewage and sludge themselves are more difficult to control directly as these agents can be concentrated. The chemicals do not present an immediate hazard to man but may be an indirect hazard by leaching into water or by volatilizing into air. In either case, the chemicals may persist and create a hazard through later aerosol dust and contact exposure. The disposal of sewage and sludge and its impact on microbiologic disease is being investigated to ascertain if workers are affected by the concentrated material and whether the populations surrounding treatment areas are susceptible to illnesses caused by the microbiologic agents in this medium. A program has been initiated to determine the dispersion of pathogens and toxic chemicals in aerosols from conventional wastewater treatment plants.

B. Wastewater and Sludge Research - Importance of Data to EPA Operations and New Initiatives

At present there is insufficient health information for the development and defense of criteria necessary to insure the protection of human health from the disposal of wastewater and sludges. There continues to be an increase in land treatment and disposal plus disposal of wastes into waters. Additionally, there have been increases in the number and size of sewage treatment plants. Along with the requirements of regulatory procedures, these growth patterns point out the need for increasing the research efforts to determine the posible adverse health effects associated with land treatment and disposal of wastewater and sludges. Research is required to further elucidate pathogen dispersion, especially of viruses in aerosols formed by spray irrigation of sludges and wastewaters; to determine the persistence and transport of pathogens and toxic substances in the soil of land applicator sites and on to the food chain; and to assess more fully the health of populations residing in locales where land disposal of wastewater and sludges is carried out.

The health effects research program has planned investigations to meet needs in this area. These ongoing activities include laboratory and field investigations on the potential of bacterial and viral survival and movement at land reclamation sites utilizing sewage sludge; studies on the health effects associated with exposure to land sites using treated wastewater effluent; monitoring and epidemiological studies of the health implications of aerosols produced by spray irrigation of treated sewage effluents; studies on the potential of contaminants present in sludge applied to land entering the human food chain; and laboratory and field investigations to develop an acceptable methodology for sampling and analyzing sludge for biological, organic, and inorganic chemical content.

C. Marine and Fresh Recreational Waters

Other research in the water quality area include studies to assess the health implications of pollution of marine and fresh recreational waters. Every year thousands of persons develop acute illnesses of the gastrointestinal tract and ear, nose and throat as a result of recreational activities in marine waters. Although some microbes are known to be in the marine waters, the etiologic agents and any critical concentrations are unknown at present. Epidemiologic-microbiologic studies are being conducted to define any causal relationships and, ultimately, to develop water quality criteria based on human health considerations. Accompanying such efforts is a program to develop methods to ascertain numbers of micro-organisms and to quantitate a candidate chemical indicator (coprostenol).

Paralleling the work on marine water, a program is underway to assess the quality of fresh recreational waters. Epidemiologic-microbiologic studies are aimed at detailing the association between incidence of acute disease and the presence of microbiologic indicators. Such data would provide a basis for water quality criteria for fresh recreational water.

D. Fresh and Marine Water Research - Importance of Data to EPA Operations and New Initiatives

As in the area of wastewater and sludge research, additional studies are required to more clearly define the effects of waste disposal in water. Research is required and is planned to determine pathogen concentrations which may occur in primary contact marine waters without jeopardizing human health; to develop valid microbiological criteria for shellfish growing waters as hepatitis has been shown to be epidemiologically related to consumption of oysters from contaminated beds; and to correlate human health effects to select indices of pollution in primary contact fresh recreational waters.

Other planned investigations in the marine and fresh recreational water area include cataloging all U.S. beaches according to microbiologic quality and continuing current studies in the etiology of amoebic meningoencephalitis which is believed to be acquired following swimming in fresh or brackish waters.

Availability of EPA Health Research Data

While our research information is, of course, frequently published in the open literature, it is also channeled into guidelines and criteria documents for regulatory actions. As noted earlier, EPA health research on wastewater and sludges is a relatively new activity and, at this time, data are not readily available. Scientific and technical assessment reports are periodically prepared for non-regulated pollutants, and they attempt to indicate where research information is limited. These reports, as in the case of the guideline and criteria documents, cover the technical literature from both EPA and non-EPA research.

Summary

In summary, I would say that EPA's health research program is diverse, combining a spectrum of expertise in the biological sciences, and addressing a multitude of environmental concerns with research on wastewater and sludge health effects being an area of growing concern with expanding research activity. Perhaps one of our biggest dilemmas is maintaining diversity; that is, planning and conducting the program to allow flexibility. We find that as research continues both within and outside the Agency, new and varied environmental problems constantly emerge which require our attention. We want to be able to address these emerging issues, as well as the known problems, as fully as possible so that rational decisions can be made to protect our environment and ultimately, our public health.

AN OVERVIEW OF LAND TREATMENT OF WASTEWATER IN THE UNITED STATES AND WATER PROGRAMS OPERATIONS*

Belford Seabrook**

Introduction

When one talks about land application of wastewater, it is generally assumed that the wastewater needing treatment would come from municipal and/or industrial sources. However, a significant amount of wastewater in the United States comes from highway runoff and street storm drains. A lesser amount comes from animal feed lots and agricultural land. In total, the wastewater, runoff wastes and debris from highway, street and farm sources undoubtedly exceed the wastewater from municipal and industrial sources. In spite of the enormous quantities of non-municipal wastewater, little is being done in this situation for several reasons. The principal reason is that the problem of non-municipal wastewater does not quality for the EPA construction grants program because the facilities for treating such wastewater, to the extent that treatment facilities exist, are for the most part not publicly owned. Another reason is the relatively high cost of treating wastewater from non-municipal sources.

Land treatment for many of these wastes should be considered more carefully. Records of experience and research studies show that:

1. land treatment of wastewaters is not new;
2. land treatment is a significant factor in past and current management of wastewater;
3. the use of land treatment is evolving from a disposal concept to a concept of treatment, utilization and reuse;
4. land treatment methods, where appropriate, can play a significant role in future wastewater management plans; and
5. land treatment can be cost effective.

Existing Land Treatment Systems with Long Experience

Some of the long time examples of successful operation of land treatment systems for wastewater effluents are:

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* Mr. Seabrook's address did not get transcribed. Much of his talk, however, is contained in this edited version of his presentation at the Symposium on Wastewater Treatment and Disposal Technology in Argentina in June 1976, sponsored by the Pan American Health Organization.

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1880 - Wyoming, USA
1891 - California, USA
1895 - Berlin, Germany
1896 - Melbourne, Australia
1902 - Mexico City, Mexico

In the early stages, land application of wastewater effluents was a disposal operation. It became a treatment and reuse technique when the water became useful and important in irrigating crops and orchards that otherwise could not be grown in water short areas. The use of treated wastewater from municipal and industrial sources for irrigation has been practiced for many years in various countries on a limited scale. Interest in renovated wastewater for irrigation water is now on the increase and its use is now being considered by many parks, golf courses, and other facilities in water short regions. Reuse of treated wastewater is also being practiced by certain industries.

We must keep the priorities clearly in mind when handling wastewater. Unfortunately the wastewater priorities for a farmer are not the same as for water pollution control administrators. For water pollution control, the first priority is what to do with the water. Should it be used for agriculture, or reused for industry, or renovated and discharged to underground aquifers? Regardless of the fact that water is needed for crops, crops do not need water every day; whereas wastewater is produced every day, including the holidays during the wintertime.

Public Acceptance is the Limiting Factor. Public acceptance is the primary factor limiting the use of soil treatment systems for wastewater. The term "disposal" should be avoided unless you actually mean what the lexicographer defines the word disposal to be, that is, distribution, discarding, or throwing away. "Disposal" often connotes an undesirable effect in the minds of the public. Instead, it is suggested that the terms, land application, land treatment, or soil treatment might be more appropriate in most instances where some useful benefit is being achieved. Although a rose may be just as sweet by any other name, the public does not always think so.

Much is known about the beneficial uses of wastewater, such as crop irrigation in arid zones, removal of N (nitrogen) and P (phosphorus), strip mine reclamation, and reuse by industry. Some of the unknown factors are the adverse health effects, public speculation about potential health hazards, and the full costs of land application, that is, the legal and social costs contrasted with the economic value of the beneficial uses.

EPA Wastewater Effluent Limitations. The EPA effluent limitations for publicly owned treatment works, as published in the U.S. Federal Register, [9], para. 133.102, set a monthly average water quality limit of 30 mg/liter of BOD and SS for discharge into surface streams from secondary treatment works. In the case of land treatment systems, it is proposed to require groundwater under the system to meet the U.S. public health drinking water quality standards in cases where the groundwater will be used as a drinking water supply [22]. The records from land treatment systems with long experience indicate that the quality of the effluent in almost all instances is vastly better than the monthly average water quality limit of 30 mg/l of BOD and SS for the effluent from secondary treatment works.

Important Factors - Design & Operation. There are two important factors that apply equally in conventional non-land treatment facilities and in land treatment facilities. These are design and operation. There are other important factors, of course, but these are the two most important. The same can be said about pianos and airplanes. People seem to understand the importance of these two factors, that is, design and operation, in the case of pianos, airplanes and conventional sewage treatment plants, but these factors are equally important in the case of land treatment systems.

Discussion of Land Treatment Techniques

The land treatment techniques for renovating municipal and industrial wastewaters are not sewage spreading, sewage farming, disposal of partially treated effluents on land or even the utilization of effluents for irrigation of crops.

Many proponents of wastewater recycling contribute to confusion by attempting to analogize between land treatment and one or more methods of disposal or utilization. While wastewater disposal and utilization projects may provide some information which can be extrapolated or interpolated or used to predict the performance of land treatment systems, they are not directly comparable and continued and expanded evaluation of bonafide land treatment systems such as Muskegon's are essential.

There are many examples world-wide where raw sewage has been continuously and successfully applied on particular sites for periods approaching 75 to over 100 years. The crops grown vary from strictly forage for animals to vegetables for direct human consupmtion. Other than obnoxious odors, there have been few reported adverse changes in the local environments resulting from well managed sewage farm operations. These are excellent examples of the tremendous capacity of soils to attenuate gross amounts of pollutants when properly managed. Proper management is a prerequisite of success because raw municipal sewage may contain from less than 100 ppm (parts per million) of BOD (biochemical oxygen demand) to as much as 500 to 600 ppm, depending on industrial and stormwater discharges and infiltration of groundwater into sewers. It is not uncommon for the BOD content to vary over this range of values in a 24 hour period. Such wide variations cause difficulties in adjusting rates of application on land areas without creating problems. Sewage farms have been continuously operated for long periods of time by dedicated attention to detailed management schemes and their success must be judged in terms of what they were designed to do. They were not designed to renovate wastewater for unrestricted reuse. Crop and soil management practices are usually given little weight where the main purpose of irrigation is disposal of the effluent.

In water short regions, there are many examples where sewage effluent has been used to irrigate crops, parks, and golf courses at rates just sufficient to maintain good growth of vegetables. Effluents from secondary treatment plants or lagoons contain only a small fraction of the BOD originally present in raw sewage and can be applied on land by ordinary methods of irrigation. In secondary treatment plants or lagoons, large quantities of oxygen are supplied in primary effluents to stimulate the growth of aerobic microorganisms. The aerobic microorganisms assimilate and decompose soluble and suspended organic substances. By the removal of dead and living microbial cells by sedimentation, 80 to 90 percent of the BOD originally contained in sewage is also removed. Thus, from sewage having an average BOD load of 200 ppm, secondary effluents will contain 20 to 40 ppm of BOD.

On the other hand, effluents from secondary treatment facilities usually contain about 80 percent of the nitrogen, 70 percent of the phosphorus, 90 percent of the potassium, and 20 to 40 percent of the trace elements which were present in the original sewage. Because of its content of nutrients, when secondary effluents are discharged into streams, excessive growth of aquatic plants is often the end result. The annual excessive growth of aquatic plants and the oxygen consuming processes of residue decay often lead to a deterioration of stream water quality.

Therefore, many people have proposed that soils and their biological systems be used to provide tertiary treatment and nutrient removal. Advocates of the use of land treatment systems for renovating wastewaters point to numerous examples where crop plants have responded more favorably to the use of sewage effluent for supplemental irrigation than to equivalent amounts of irrigation water from other sources. However, the main objective in each case was to utilize the wastewater to grow the agricultural crops. Thus, findings from these projects are used to justify the land treatment system for renovating wastewater. Where crops are used in land treatment systems to provide maximum nutrient removal from the wastewater however, the aim is to apply as much wastewater as possible without decreasing plant growth.

Three Major Land Treatment Methods plus Combinations. The three distinct methods of land treatment are: (1) overland flow, (2) rapid infiltration, and (3) crop irrigation or slow-rate infiltration.

An overland flow land treatment system is used for soils with very low infiltration and/or percolation capacities. Wastewater renovation by the overland flow systems requires the filtering action of a close growing vegetation, generally adaptable grasses, and the controlled flow of a thin film of wastewater over the soil surface to maximize re-activity between the wastewater pollutants and soil microbiological and physical/chemical processes at the soil/water interface.

Rapid infiltration/percolation systems are used where deep permeable soil materials are available. The rapid infiltration/percolation basins renovate a few to several hundred feet of water per year by proper management. Proper management implies alternating flooding and drying periods to manipulate the soil microbiological mass, promoting nitrification and denitrification processes and the decomposition of organic materials filtered out of the wastewater at the soil surface. Degrading accumulated organic materials by aerobic microorganisms during the drying cycle facilitates restoration of the water infiltration capacity of the soil filter. Sometimes, grass is grown in the basins to aid in maintaining infiltration capacities during the flooding cycle.

The crop irrigation land treatment system may embody various methods of applying treated effluents by spray applications or flooding on land through furrows or borders. The crop irrigation treatment method is variously called: (2) irrigation treatment system, (3) living filter system, (4) slow rate infiltration system, and (5) low rate system. Since the main objective is to renovate wastewater for reuse, maximum amounts of wastewater are applied that are consistent with maximum crop yields.

In addition to the three methods of land treatment, a combination of these methods may be used. For example, one might use the overland flow method to treat the wastewater if you have an impervious soil, producing a surface discharge. The effluent from the overland flow treatment system might then be conveyed to an underground aquifer by rapid infiltration. Any of these treatment methods can be used when the sewage effluent is applied with "spray irrigation" or with "flood irrigation". Usually the energy requirement for flood irrigation is substantially less than for spray irrigation.

Spray Irrigation is not a Land Treatment Method. While on the subject of definitions, "spray irrigation" is not a land treatment method, rather it is a means of applying water to the land. The water can be pure water or wastewater. Another method of land application is flood irrigation. Ridge and furrow irrigation is a variation of flood irrigation in furrows.

Survey of 100 Existing Land Treatment Facilities.

In 1972, the Research Foundation of the American Public Works Association conducted an on-site field survey of approximately 100 facilities in all climatic zones in the United States where community or industrial wastewaters are being applied to the land. The report is entitled, Survey of Facilities Using Land Application of Wastewater, [1]. There are many hundreds of land application systems in use in the United States, but the 100 facilities surveyed were relatively large, long-established operations. These were selected to obtain as much information as possible on the operating experience of those using this technique. The municipal systems were predominantly located in the western and southwestern portions of the United States, and the industrial systems were generally sited in the northeastern region, because this is where the majority are in service.

Highlights

The following highlights from the APWA field Survey are presented to give a composite picture of the observations made during the land application site visits:

1. Communities generally use their land application system on a continuous basis. Food processing plants, the predominant industrial users of the system, generally use discharge-to-land systems for three to eight months per year;
2. Ground cover utilized for municipal systems is divided between grass and crops. Industries generally use grass cover;

3. Land application systems are generally used on a daily basis, seven days per week;
4. Application rates for crop irrigation are very low in terms of inches of water per week. Two inches or less was commonly used. (Two inches per week equals 54,000 gallons per acre per week);
5. Many types of soils were used, although sand, loam and silt were the most common classification given. Two systems using applications over many feet of sand were applying up to 8 inches per day once a week, and one system on clay was applying a daily rate of 0.1 inch;
6. Most operating agencies, municipal and industrial, are planning to either expand or continue their application installations. The few examples of systems which had been abandoned were due to either the desire to make a higher use of the land, or because of reported overloading and incompetent operation of the land application facilities;
7. Industries surveyed generally treat their total waste flow by land application. Practices of municipalities varied from less than 25 percent, to all the wastewaters discharged;
8. Secondary treatment is generally, but not always, provided by municipalities prior to land application, oftentimes accompanied by lagooning. Industries, using this technique frequently treated their process wastes by screening only;
9. Spray irrigation is the most frequently used (57 facilities) method of application, although most municipalities use more than one method. Ridge-and-furrow irrigation is used at 23 facilities, and flooding irrigation by 34 systems. Industry generally used spray irrigation;
10. Land use zoning for land application sites is predominantly classified as farming, with some residential zoning in contiguous areas;
11. Wastewater generally is transported to the application site by pressure lines, although a number of municipalities are able to utilize ditches or gravity flow pipelines;
12. Many municipal land application facilities have been in use for several years -- more than half for over 15 years. Industrial systems generally have been in use for a lesser period of time;
13. Renovated wastewater is seldom collected by under drains; rather, evaporation, plant transpiration, and groundwater recharge take up the flow;
14. Land application facilities generally do not make appreciable efforts to preclude public access. Residences are frequently located adjacent to land application sites. No special effort is made to seclude land application areas from recreational facilities and from those who use these leisure sites;
15. Monitoring of groundwater quality, soil uptake of contaminants, crop uptake of wastewater components, and surface water impacts is not carried out with any consistency.

Survey Conclusions

The following conclusions are based upon the field investigations of 67 municipal and 20 industrial facilities which yielded usable data as well as information from more than 300 questionnaires, a bibliographic review, and numerous foreign contacts.

Note: At the time the report was prepared, EPA had not adopted a definition of secondary treatment: Thus, the term "secondary treatment" is used throughout the APWA report to connote treatment beyond that normally given by primary treatment and not that defined by present regulations [9].

1. Land application of wastewaters from community and industrial processing sources is practiced successfully and extensively in the United States and in many countries throughout the world. Facilities investigated handled from less than 0.5 mgd, providing service for sixty days per year, to more than 570 mgd applied on a year round basis.

2. Various degrees of municipal sewage pretreatment are practiced prior to land application.

3. Under proper conditions, land application of wastewater is a workable alternative to advanced or tertiary treatment of municipal wastes. Successful operations now in use generally rely upon conventional treatment processes to pretreat sanitary wastes equivalent to secondary treatment. Prior to application to land areas, industrial wastewaters, on the other hand, often receive no conventional treatment, other than screening.

4. Land application of wastewaters is practiced for several specific reasons. Among the major reasons are: To provide for supplemental irrigation water; the desirability of augmenting groundwater sources; excessive distances to suitable bodies of receiving waters or extraordinary cost to construct facilities to reach suitable disposal sites; economic feasibility, as contrasted with the cost of construction and operation of advanced or tertiary treatment facilities; and inability of conventional treatment facilities to handle difficult-to-treat wastes.

5. Land application of wastewaters can be considered as a part of a water reuse cycle. Land application is not land disposal inasmuch as wastes are not placed inertly and left on land areas; rather, they become a part of a dynamic system of utilization and conversion of the liquid and the nutrient components contained therein. (This requires caution in application of non-amenable wastewaters which cannot become a part of this recycle-reuse process.)

6. Present land application facilities generally are not "stressing" the system. Even where efforts were being made to use land as the only point of disposal, application rates were generally conservative, and the soil-plant components of the system were not stressed to limits of assimilation or used to their capacities, thus providing a large factor of safety.

7. Small communities and food processing industries will probably continue to be the principal users of land treatment of effluents for the near future. The ability to assemble the necessary land at proper prices and without adverse effect on local land use practices, tend to favor the use of land application systems for such smaller installation. However, stringent requirements on discharge of effluents to receiving waters, energy shortages, favorable experiences such as here at Muskegon, and/or a number of other conceivable economic-environmental factors could make land application feasible and workable for larger communities or other wastewater sources.

8. A variety of beneficial uses are being made of wastewater effluents. Uses include irrigation of parks, golf courses, cemeteries, college grounds, street trees, highway median strips, sports grounds, ornamental fountains and artificial lakes. Wastewater effluents are also used to irrigate many types of

crops, including grasses, alfalfa, corn, sorghum, citrus trees, grapes, and cotton. Forest lands also are being irrigated in many areas. Groundwater augmentation to prevent salt water intrusion is being practiced. In Mexico, a wide variety of truck garden crops have long been irrigated with effluent. Crops appeared to benefit from both the nutrients and the increased amount of water which is applied.

9. A large variety of potential opportunities for land application of wastewater exist in many communities that are not currently using the opportunities listed in item 8.

10. The sale of effluent for beneficial use has been generally unsuccessful.

11. Successful operation of a land application system requires the inputs from a variety of disciplines. For many systems, the services of a geologist and environmental engineer are required. For systems designed to augment the indigenous crop water requirements by supplemental irrigation, the advice and guidance of an agronomist and soils specialist will be needed. For larger systems, social and behavioral scientists, as well as medical health personnel may be required to assist in evaluating and securing acceptance of this alternative means of treatment.

12. Operation of land application facilities can be accomplished without creating a nuisance or downgrading the adjacent environment. The survey indicated that a majority of the facilities were conducted by well trained personnel, aware of the need for careful operation of the systems. Training, supervision and adequate monitoring or pertinent factors are necessary to ensure that systems will not be overstressed. If ponding on the land is not allowed, odors will not be a problem. The hazard of creating other adverse effects on the environment by discharging treated effluent on land is minimal.

13. Environmental analysis of the effects of land application facilities reflects a general improvement of the environment rather than impairment of the indigenous ecology. Many facilities were observed where the effluent provided the only irrigation water available. Land values for sites with a right to such wastewaters were greater than that of adjacent land because crop and forest growth was enhanced, and use of potable water supplies reduced. Farming and recreation potentials exist, as well as improved habitat for wildlife.

Treatment of wastewater prior to land application has generally been dictated by the desire to use the best practical means consistent with available technology and to minimize any adverse effects upon the environment. Land application of wastewater by eliminating direct discharges of effluent into receiving waters could be regarded as satisfying the ultimate national policy goal of "zero discharge" of pollutants.

No instances of health hazards were reported from any existing facilities, although the State of Delaware indicated concern over possible virus transmission.

14. Local public opinion -- objection of becoming the major recipients of somebody else's waste -- could be a major limiting factor in the development of large land application systems at distances from wastewater sources. Psychological concern over distasteful characteristics of effluents can result in distrust of the ability of public agencies to operate, control and manage such systems.

15. Monitoring of land application facilities and effects has been minimal and mostly inadequate. Few states have taken an active role in requiring use of monitoring facilities, apparently because there was no direct discharge of effluents to receiving waters.

16. Energy requirements for land application systems require careful consideration. Energy requirements associated with land application techniques for tertiary treatment may be substantially less than other means of treatment and effluent management. This factor deserves further evaluation.

17. The nature and quantity of receiving waters must be carefully evaluated prior to diverting effluent to land application. Few existing systems were found that used underdrains to collect the renovated effluent. Rather, the groundwater aquifers received the flow. If a land application area is adjacent to the receiving waters, much of the groundwater may serve to augment the flow into the receiving waters by a gradual seepage into the drainage basin. Elimination of direct wastewater discharges to a stream could unbalance the flow regimen associated with downstream beneficial uses, inhibit desirable dilution of waste discharges, interfere with the tempering of thermal water discharges, and permit the intrusion of saline waters into normally freshwater zones. The impact of effluent diversion into land areas with respect to the basic principle of riparian water rights must be considered where irrigation is planned as an alternative to discharge into surface waters in some areas.

18. When wastewater is discharged to land and this method is used as a means of advanced treatment by natural means, the land must receive priority for this use over other optional land uses. The needs of crop production, recreation and other benefits can be in conflict with the utilization of a land application system for the treatment of wastewaters. For instance, the planting, cultivation and harvesting of crops and the use of recreation facilities may interfere with continuous application of wastewater onto land areas. The need for the system to either utilize all of the flow or provide sufficient retention storage for needed periods of non-operation must be considered. The objective of providing adequate treatment of the effluent cannot be sacrificed for other needs and uses of the land; proper handling of the wastewater must be the first priority.

19. Choice of ground cover can play an important role in the success of a land application system. Properly managed ground cover is important in maintaining an open soil surface that will permit infiltration and remove nutrients like phosphorus and nitrogen. If crops are not harvested, nutrients will not be removed unless lost by denitrification processes that occur during overland flow.

20. Land application facilities that have been used for many years are available for the study of long-term effects of such use. Specific evaluation of established systems in the various climatic zones would appear to be more fruitful than new research installations for determining long-term effects upon soil, vegetation, groundwater, and the indigenous ecology, or on the health of site workers and adjacent residents. However, evaluations of these established systems are often limited in value by the inability to define past practices, to obtain satisfactory controls, to have the necessary variety of treatments, and the fact that many operations were for disposal rather than treatment of wastewater. Consequently, careful evaluation of carefully designed large operational systems such as Muskegon's here are particularly needed and important.

21. Observations in the field and surveys of land application systems did not reveal the existence of specific health hazards and disclosed very little

concern over threats to the health of on-site workers, residents of neighboring areas, domestic animals or wildlife, or of those who consume or come into contact with land-applied wastewaters. Some concern over potential health hazards was, however, expressed or inferred by officials of some state agencies who supplied information about their policies on land application of effluents as an alternative means of wastewater management. Concern over the "unknown" was expressed for such factors as potential viral and pathogenic hazards resulting from dissemination of aerosol sprays or mists and contacts with sanitary and industrial sludges residues.

While the current studies did not disclose cause for such concerns, the bibliographic abstracts prepared as an integral part of this investigative project do include references describing possible health hazards which warrant further study and these potential problem areas should certainly not be ignored [4].

U.S. Environmental Protection Agency - Construction Grants Program

The U.S. Environmental Protection Agency (EPA) and its predecessor agency have a long history of involvement with land treatment of municipal wastewaters, including industrial wastewaters that discharge into municipal treatment systems.

Public Law 84-660. The basic law which authorized U.S. Government grants for publicly owned municipal sewage treatment works is the Federal Water Pollution Control Act of 1956 (PL 84-660). This Act was amended a number of times, the last time being in 1972. PL 84-660 was administered by the Federal Water Pollution Control Administration of the U.S. Department of the Interior, until the U.S. Environmental Protection Agency was formed on December 4, 1970 by an act of the U.S. Congress, and these water pollution control activities, along with other environmental activities from other U.S. Government agencies, were transferred to EPA.

PUBLIC LAW 92-500. The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), the legislative history of the Act, and the regulations which have been issued in accordance with the provisions of the Act, provide the statutory basis for consideration and funding of land application systems in the treatment of municipal wastewater. The rationale and goals within which land application systems are to be considered are contained in the following sections of the Act:

Section 208 - Areawide Waste Treatment Management
Section 201 - Facilities Planning
Section 304 - Best Practicable Treatment Technology (BPT)
Section 212 - Cost Effectiveness Analysis

Among other things, the 1972 Act (1) increased the amount of the Federal construction grant to 75 per cent of the eligible costs of municipal treatment works, (2) provided for the first time that Federal grant funds could be used for land acquisition costs in land treatment systems if the land was "an integral part of the treatment process," and (3) required that all alternative treatment systems and techniques must be evaluated and only the most cost-effective alternative could be built if Federal grants were used. Under PL 84-660 the equipment and hardware used in land treatment systems were eligible for Federal construction grants, but the land acquisition costs were not eligible.

Summary of EPA Requirements for Land Treatment Systems

There are two basic documents containing EPA requirements for land treatment systems. These are the guidelines and a document entitled, "Alternative Wastewater Management Techniques for Best Practicable Treatment," or "BPT" for short [22].

The cost-effectiveness guidelines are Appendix "A" to the EPA construction grants regulations. They require the grant applicant to evaluate three alternatives for each project. The alternatives to be considered are: First, treatment and discharge; second, land treatment; and third, reuse, such as for industrial process water. The cost-effectiveness guidelines describe how to conduct an engineering economic study for a project and evaluate these three alternatives. The guidelines are based on a planning period of 20 years at an interest rate determined by the U.S. Water Resource Council. The current interest rate is 6 1/8 percent. The guidelines are based on the total cost, that is, capital cost plus operation and maintenance cost, in addition to cost factors such as social and environmental concerns. Further details concerning cost-effectiveness analysis are found in the references [15, 23].

The second document, which is usually called "BPT," sets the criteria for the alternative wastewater management techniques. For wastewater treatment and discharge to surface waters, the basic criteria are secondary treatment plus whatever additional treatment is required to meet water quality objectives. For land treatment, the primary goal is to protect the groundwater, and in this regard three separate criteria have been established. First, where the groundwater is used as a drinking water supply, the aquifer must continue to meet the chemical, biological and pesticide criteria in the drinking water standards. Note here that we are talking about the groundwater and are not saying that the water must meet drinking water standards before it is applied to land. The second category is where the groundwater has a potential to be used as drinking water even though it may not be used for that purpose at the present time. In this case, the chemical and pesticide standards apply, but the biological standards do not apply. Lastly, there is a general category of groundwaters which are not now being used as drinking water and would clearly never be used as drinking water. In those cases, the ten EPA Regional Administrators, working with the State and grant applicant will develop the criteria for the system.

Where a land treatment system discharges to surface waters such as where there are underdrains, then the requirements for wastewater treatment and discharge to surface waters must be met. For reuse systems in which the water is ultimately either applied to the land or returned to surface waters, the appropriate criteria for treatment and discharge or groundwater protection must be met.

The EPA Construction Grants Program provides funds for both land treatment and conventional treatment systems. It does not make grants for "land disposal" systems. This may seem to you to be a distinction without a difference, but I assure you there is a vast difference between "disposal" and "treatment."

Some Key Issues Under Public Law 92-500

I would now like to turn to some key issues that arise out of these land treatment requirements under the sewage treatment works construction grants program for publicly owned facilities.

1. Isn't EPA inconsistent to require drinking water standards for land treatment, but only secondary treatment for discharges to the rivers and streams?

   There is no doubt that we have different requirements for different cases. In the case of surface waters, we are dealing with a fairly dynamic situation and typically, in an effluent limited segment where the secondary treatment requirement governs, we are dealing with some dilution effect. Where this is not the case, water quality standards require effluent limitations more stringent than secondary treatment. Groundwater seems to be significantly different. There is little mixing, and movement is extremely slow, many times in months and years. As a result, we have to be much more careful to protect groundwater drinking water supplies. Another important factor is that groundwater is usually obtained from wells for drinking water. Only minimum treatment, typically only chlorination, is given before consumption. This is in contrast to surface water which usually receives chemical treatment and rapid sand filtration.

2. Don't most States require secondary treatment before land application?

   It looks like about half the States do require "secondary treatment" before land application. I think, however, a clear distinction must be made between the term "secondary treatment" as those States are using it, and the same term as defined by the EPA under PL 92-500. Having heard many States discuss their requirements, at State conferences, I think what they really mean is some form of biological treatment following plain sedimentation. They do not mean a 30 day average BOD of 30 mg/l and suspended solids of 30 mg/l. Most land treatment systems have a storage pond of a considerable capacity as an essential part of the system. As a result, what we find in practice is that the required biological treatment is accomplished in the storage pond before land application.

3. Does EPA require land treatment to be considered for every grant project?

   YES. However, the degree of consideration obviously will vary depending on the type of project. This requires a great deal of judgment on the part of the grant applicant. Where sewage treatment is involved, we expect land treatment to be considered in some detail. Conversely, there are other projects where land treatment is not a suitable alternative, and this can be rapidly determined. Let me repeat, however, for every project we expect the land treatment alternative to be considered.

For example, where there is an interceptor sewer for connection to an existing regional sewage treatment system, an alternative to the interceptor may be establishing a small land treatment system rather than a regional consolidation.

4. Do land treatment projects require a permit?

   If the land treatment system results in a discharge to surface waters such as where there is an underdrain system, then a permit under the National Pollutant Discharge Elimination System is required. However, if there is no discharge to navigable waters, then a permit is not required by EPA. Of course, many States do require permits for land application of wastewaters. Even in those States which do not require a permit from the State Health Department, there may be a requirement in view of legally established water rights to obtain a permit for land application of the wastewater.

5. What parts of a land treatment system are grant eligible?

   PL 92-500 is specific that the cost of land which will be an integral part of the treatment process is grant eligible. In a Program Guidance Memorandum, EPA has defined this as the land used in the treatment process, that is, the land which is actually wetted during the treatment, and has broadened this to include buffer zones and small non-wetted areas between spray circles. However, the land under access roads and storage ponds is not grant eligible. The construction of access roads and storage ponds, as distinct from the land acquisition cost, is grant eligible.

6. What about the fact that land treatment provides a higher degree of pollutant removal and treatment of wastewater than conventional treatment such as activated sludge? Should that enter into cost-effectiveness?

   As EPA has defined cost-effectiveness, the answer is NO. As I mentioned before, there is provision in the cost-effectiveness guidelines to consider non-quantifiable benefits such as social and environmental factors. Fundamentally, however, the cost-effectiveness approach is to determine the least total cost alternatives for achieving the water quality objectives. The logic of doing more costly projects because it results in more benefit does not hold up when carried to the extreme. For instance, evaporation in condensing the wastewater would remove substantially more pollutants although at a tremendous cost. This does seem a reasonable approach to pollution control.

I hope that this presentation has given you an insight into the way the EPA Office of Water Programs views the role of land treatment of wastewater in the United States water pollution control programs. Since land treatment will play an increasing role in treating our wastewater, evaluations of systems like this large prototype spray irrigation-land treatment system at Muskegon is extremely important.

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ENVIRONMENTAL PROGRAMS, EXTENSION SERVICE - U.S. DEPARTMENT OF AGRICULTURE

Harry G. Geyer*

I was quite pleased with the comments that I heard from the preceding speakers. I think they addressed something which is rather close to our interest. At the Extension Service our primary responsibility is that of education. That is our total responsibility. We think we have the opportunity to assist in this type of effort since Extension does constitute a national system that embodies the technical competencies of land-grant universities and their staffs throughout the United States which embraces about 16,000 professionals. We also utilize research information from universities, experiment stations and USDA Agricultural Research Service, as well as that of other Federal agencies, and private institutions. Our responsibility is to interpret this information and get it to the appropriate audience, be it Federal or local decision makers to enable them to make rational decisions. Since we are affiliated with the Department of Agriculture we are interested also in a system that will enhance the efficiency of agricultural production. We are therefore interested in the aspects of land utilization or wastewater treatment through the land system that will contribute to efficient agricultural production. We have cooperated with other agencies in this effort through the EPA, USDA, University Committee to address this subject at a conference held at Urbana, Illinois. We addressed various parameters that we felt needed attention which would give us needed information to assist decision makers at the local and national level. The Extension Service at Michigan State hosted a conference on this very subject for the purpose of broadening understanding of Extension personnel at the regional level. Participants included the Corps of Engineers and EPA.

From an educational standpoint the Muskegon project is one from which we can learn many things. Perhaps it is most important to learn more about health safety. If safe, there should be opportunities at Muskegon where privately owned land could also be utilized for wastewater treatment. We do need more information on those wastewater borne organisms that are pathogenic as well as those that are non-pathogenic. There is the need for information that will enable us to adequately inform those who are concerned with this potential as a threat to human health, as well as animal health and from an agricultural standpoint. In agriculture there is concern for the implications to livestock, especially on the survival data of pathogenic organisms. We know for example in California, where irrigation is practiced on grazing land, that the incidence of tapeworms in cattle is much higher than it is on non-irrigated land.

Thus, if it were intended to utilize this system on privately owned land, or if Muskegon were to utilize this land for grazing purposes, I feel there is a need to establish the parameters whereby health safety can be assessed. We must have this information.

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I feel it warrants reiteration that we must know the implications of land treatment on health safety. There is the need to better understand the factors which influence survival and infectivity of the various species of these organisms such as chlorination and ultraviolet radiation. There is a need for information that will show economic advantages or disadvantages for using municipal wastewater. To what extent will it reduce the need for commercial fertilizers?

As long as the recipient, user, or decision maker has questions to which we do not have answers, it is going to be rather difficult to convince them to accept a system that is contrary to currently accepted philosophy. We feel that this is the type of information we need. We have the capability for transmitting information, but without factual information, it is difficult to accomplish.

WASTE MANAGEMENT RESEARCH IN THE AGRICULTURAL RESEARCH SERVICE - U.S. DEPARTMENT OF AGRICULTURE

Jesse Lunin*

The Agricultural Research Service (ARS) is the arm of the U.S. Department of Agriculture that conducts research on crop production and protection, livestock, soil and water resources, marketing, nutrition, and all other aspects of agriculture with exception of those areas related to forestry. Although administratively organized on a regional basis, there is a National Program Staff at Beltsville, Maryland that has the responsibility of developing and coordinating national protrams. With this type of organizational structure, ARS is uniquely equipped to work on programs of regional and national significance. We have the capability for developing multidisciplinary approaches to problems with include soil scientists, plant scientists, engineers, hydrologists, chemists, etc. In addition, we work very closely with the State Agricultural Experiment Stations and have many cooperative projects. We also have similar cooperation with many State and Federal agencies. We have had excellent results with these cooperative efforts.

Our first project dealing with municipal waste management was initiated in Phoenix, Arizona several years ago. The cost of water there is extremely high and the demand is increasing rapidly. The groundwater table is also dropping at an alarming rate. Our U.S. Water Conservation Laboratory at Phoenix, Arizona initiated a study on the renovation of municipal wastewater using rapid infiltration through basins designed to recharge groundwater. Their studies demonstrated that their pilot system was doing an acceptable job of renovating secondary sewage effluent and, at the same time, adequately recharging the groundwater. Based on the sucess of their studies, the city of Phoenix has constructed a much larger rapid infiltration system for tertiary treatment of a significant portion of their municipal wastewaters.

In the latter part of 1971, the Blue Plains sewage plant in Washington, D.C. was faced with the problem of upgrading their sewage treatment facilities and disposing of large quantities of sludge. Other municipalities were facing similar sludge disposal problems with increasing environmental constraints. Recognizing land application as a viable alternative, a multidisciplinary team was established at Beltsville, Maryland to develop environmentally safe practices for sludge disposal, and to develop guidelines and methods for beneficial use of sludge as a soil amendment. This group is now a part of the Biological Waste Management Laboratory.

Initial endeavors were directed towards developing and evaluating a trench method for disposal. Field tests have subsequently confirmed that under most conditions, this is a very satisfactory procedure. Other studies were initiated dealing with surface applications of both liquid and partially dewatered sludge. Results indicated that a good approach to surface application would be to compost the sludge. Initially the project involved composting digested sludge. When raw sludge was inadvertently shipped for a couple of weeks, intolerable odors developed. A challenge was given to develop a composting process for raw sludge in which no objectionable odors would be developed. With support from EPA and the Maryland Environmental Services, they proceeded and developed a process which has already been put into use by two municipalities; Bangor, ME, and Durham, NH. Research is continuing to refine the process for more effective pathogen control and cost reduction. Besides the composting work, other studies are directed toward control of heavy metals, nutrient benefit to crops, effects of sludge on physical properties of soil, sludge nitrogen transformation, and survival and movement of pathogens in sludge-amended soils.

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There is another ARS municipal waste management project headquartered at St. Paul, Minnesota. This project initially was developed to investigate land application of sludge for beneficial crop production with emphasis on heavy metal problems, plant nutrient relationships, effects on soil physical properties, and overall environmental aspects. Many studies have been initiated to determine effects on crop yields and crop quality. Perhaps the most unique project is one designed to demonstrate safe, efficient, and practical methods for land application of sludge on sloping terrain in harmony with agricultural usage while controlling pollution of surface and groundwaters through a program of total water management. This is a complete watershed system on a 16-hectare watershed terraced with grassed backslope terraces having separate surface tile inlets. Sludge storage and application facilities are provided. Drainage is stored in a runoff reservoir to monitor and control potential pollution. It is designed to collect information on specific practices for land application of sewage sludge so that safe management guidelines can be developed for various soil, crop, and climatic situations in northern climates.

Another project at St. Paul, Minnesota is designed to develop agricultural practices for maximum nitrogen removal of sewage effluents. Using well-instrumented plots, corn and forage grasses are being tested under several irrigation regimes to evaluate nitrogen balances. Emphasis is being placed on efficient soil and crop management for maximum renovation under high wastewater application rates. This effort is supported by the U.S. Army Corps of Engineers.

At Morgantown, West Virginia, an ARS project is using sludge as an amendment in the reclamation of strip-mine soils. Here, sludge not only provides an improved substrate for establishing vegetative growth but also tends to minimize potential pollution hazards through improved water management. Results to date show that sludge application to an extremely acid strip-mine spoil greatly increased forage yield, even greater than that achieved by chemical fertilizers.

The ARS is also involved with land application of other types of waste. At Kimberly, Idaho the use of infiltration basins were adapted to the disposal of waste waters from potato processing plants. More recently, similar approaches are being developed for the renovation of beet sugar processing wastewaters. We also have studies dealing with land application of liquid and solid wastes from feedlots and other animal and poultry production enterprises. There are many factors in common involved in the development of these various waste management systems.

As a means of keeping abreast of current research, the Department of Agriculture has developed the Current Research Information System (CRIS). It is possible to get a computer printout of research in any area given the appropriate key words. When one requests a printout of work related to land application of wastes, he gets a rather enormous stack of material. It makes me wonder whether there is an adequate job of coordinating this tremendous effort. While we have been working closely with our colleagues in the State Agricultural Experiment Stations and with other agencies such as EPA and the Corps of Engineers, I believe we can do a better job in cooperating and coordinating our efforts.

Listening to the conversations here today, many questions have been raised about this Muskegon system. Land application of wastewater is still not a well-accepted practice in the U.S. A lot of people are raising questions - citizens, wastewater treatment authorities, and regulatory groups. They all need research data to give them the background they need for determining the merits of land treatment and to help them develop guidelines for building and operating systems that will be effective and environmentally, economically, and politically acceptable. There is a definite need for complete evaluation of these systems. The ARS has participated and will continue to participate in such studies to the extent of its resources.

Before closing, I would just like to make another couple of observations. First, an earlier speaker talked about modeling. Modeling is getting to be very popular now, and I think there is a place for modeling. However, I think we need to look at it very cautiously. There is no universal model that will apply to a big system like an agricultural watershed. When working with models, there is a need to develop scientific questions for which we seek definite answers. We have to ask the right questions. We have to be able to define the problems. In order to develop a model, you need to be able to understand the system and describe it mathematically. Once you do this, then it is important to have some good experimental data with which to test and refine that model. Modeling must be tied in closely with experimentation. Unless you have good experimental data to test, then the computer output has little meaning. I think there is a need for modeling because it is obvious that you can't study all phases of large agricultural watersheds under all of the conditions that a model can help to simulate.

Second, there are a number of research endeavors at Muskegon. It is important that they be drawn together to tell the entire story. Data are needed from the laboratory, the greenhouse, small field plots, large field plots, water quality studies, etc. Until this information is all integrated to generate knowledge of the system from the input sewage to the outflow drainage water and the receiving streams, you have not finished the job. Just because nitrogen has moved in the soil down the root zone, it doesn't constitute a hazard unless it moves out into the aquifer or surface waters in excessive quantities. Significant progress has been made in the development of land application systems for waste management but many gaps in knowledge still exist. We must continue to stress our research efforts.

U.S. GEOLOGICAL SURVEY

Joseph T. Callahan*

Some of the things that I have heard this afternoon are encouraging in that a positive attitude has been expressed toward the use of the land to clean up wastewater.

From my reading newspapers and talking to people, I get the impression that most members of our society believe that the use of waste products to utilize the nitrogen and phosphorus is a new concept.

They have forgotten that commercial fertilizers as we know them today are a relatively new product. I can remember as a boy in New Hampshire watching the manure wagon going out to the fields in the winter and in the early spring.

I once spent five years living in an economy where all of the waste products of the people were carried out to the fields, in what we called honey buckets, to fertilize crops. I lived through five growing seasons, and remember that one knows when the growing season arrives as long as one has a nose.

I believe that populations that subsist on food fertilized with raw night soil would make a marvelous study group to determine the types and numbers of pathogenic organisms. The consumption of uncooked vegetables results in intestinal parasites. The population accepts this and routinely takes some type of medicine. The use of wastes is an effective use of a resource, and it saves energy. I really think that what is happening at Muskegon will provide good data and information for other places that want to consider wastewater reclamation as a way of solving a problem.

Others also have been assisting in the solution to the wastewater problem. For example, experiments at Pennsylvania State University, the ARS at Beltsville, a private farm in Pennsylvania, and the farms of the Campbell Soup Company are restoring wastewater on the land. These are all projects that have shown positive results that can be applied to other places.

Our groundwater model study was explained by Bill Fleck before lunch. The model of the groundwater system describes how the normal system works, and what the impact will be from the additional water. It attempts to trace the added irrigation water applied to the crops through the soil to the groundwater system and the drainage water. From the model we should be able to answer the questions, will a groundwater mound be created, and what will be the rate and direction of movement? In this study, we have built a model based on the past work of other hydrologists in the Survey, but incorporating data obtained here at Muskegon.

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For more than 80 years the Geological Survey has been engaged in studies of the streams of the United States, the groundwater systems and the chemistry of groundwater. It is only in the last 15 years that we have had the resources to do basic research into the physics of water movement, a basic question when we think about wastewater treatment.

Our hydrologists have learned to describe mathematically how a molecule of water will move through the soil and zone of aeration to the water table, and through the aquifer systems to areas of discharge. They have developed the different types of models to describe the relationship of the water in the stream to the water that is underground. They have been studying the chemistry of the waters. What we are doing here is a culmination of that, and the integration of all that past work by many specialists, and is a part of our nationwide cooperative program with local governments. Fifty percent of the funds is local and the other 50 percent comes from the Federal budget.

Beyond modeling the present system to the point where one can predict what will happen to water, an important question is how much can be put on the land? How rapidly will it move out through the drain tiles to the ditches? Beyond physical movement our interest would be in determining the movement of various ions through the system. We have successfully modeled the movement of the chloride ions in a groundwater system at Brunswick, Georgia. We think we have a valid model there and in some other of our ongoing studies. For example, on Long Island we are studying deep-well disposal of treated sewage effluent. We are doing a similar study in Florida. Also in Florida, we have studied the possible deep storage of fresh water in a saline water aquifer. A fresh water bubble in salt water was created that consisted of secondary treated waste. In Virginia, we stored fresh surface water in a salt-water bearing sand. In the process we met a number of problems. At Norfolk, Virginia, the surface water was not compatible with certain ions that were in clay in the sand aquifer in minor amounts. The chemical reaction that was taking place was causing the clay to plug the aquifer so that after a while water could not move. On Long Island in the study of sewage effluent storage we tracked the movement of the ions to determine direction and rate of movement. In New Jersey, we are studying the chemistry of water where land treatment of wastes is being tried. In the High Plains of Texas work related to Muskegon irrigation is our artificial recharge project that has been underway for about eight years. The studies concern the rate and volume of recharge to the surface and to pits, and the problems involved.

I think that in the long term this study and other studies are important because we not only conserve water for additional use, but the processes being studied improve the quality of the water and the entire environment. So, personally and professionally, I would encourage those people who are working here and who have been working elsewhere to continue their good work. I think they have done very well.

Thank you.

U.S. FISH AND WILDLIFE SERVICE

Clyde R. Odin*

I am happy to be here this afternoon to share some thoughts with you regarding the Wastewater Management System at Muskegon and related aspects of fish and wildlife and the environment.

To the best of my knowledge very few evaluation studies have been made by Fish and Wildlife people on the type of wastewater system which you have at Muskegon.

This afternoon I would like to address some items which may be of interest to you. These include: Comments on the program of the Great Lakes Area Office, Division of Ecological Services, Fish and Wildlife Service, and some impacts that a treatment system like this one could have on fish and wildlife and the environment.

The Division of Ecological Services headquarters is in Twin Cities, Minnesota. Five field offices under the North Central Region Office include: a field office at Minneapolis, Minnesota; Lebanon, Ohio; Green Bay, Wisconsin; Rock Island, Illinois; and East Lansing, Michigan. The East Lansing office was established in 1972.

The authority for the functions of the Division of Ecological Services lies in numerous pieces of Federal legislation. Several principal laws include:

1. The Fish and Wildlife Coordination Act of 1958;
2. Watershed Protection and Flood Provention Act (PL-566);
3. National Environmental Policy Act;
4. The Fish and Wildlife Act of 1956.

We study and comment on environmental and fish and wildlife aspects of:

1. The Winter Navigation Extension Program - CE-DD;
2. Section 10 permits - CE-Buffalo and Detroit Districts;
3. NPDES Permits;
4. Evaluation of harbor development projects;
5. The confined spoil program;
6. Watersheds - PL-566 projects;
7. Investigations and comment on power plants;
8. Western End of Lake Erie Estuarine Study;
9. Great Lakes Connecting Channels Follow-up Study;
10. Comprehensive Studies such as the Maumee "Level B" and;
11. Review of EIS.

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Although the Great Lakes Area Office has not worked a great deal with the Muskegon Wastewater System, we are very interested in the program and the precedent which it may be setting for future wastewater management.

Man has finally realized that the watercourses, lakes, and seas of this planet can no longer be regarded as unlimited dumping grounds for our wastes. We have watched our rivers become flowing sewers emptying into degraded lakes, and attempts to curtail this pollution have, until recently, been extremely limited. Often raw sewage is dumped directly into the water and most other wastewater receives only secondary treatment.

This does not begin to solve our water quality problem and as our nation moves into an age of energy and natural resource conservation, projects such as the one here at Muskegon take on important national and even international significance.

Utilizing biological systems for the treatment of wastewater seems to be a reasonable answer to the problem. Coastal marshes and estuaries have been shown to be tremendously valuable for waste assimilation and their worth as tertiary treatment systems has been calculated at tens of thousands of dollars per acre. Similar economic benefits seem to be demonstrated at the Muskegon Project with the apparent increase in agricultural production through the spray irrigation system.

Since the Muskegon Wastewater Management System will result in the improvement of water quality, its primary value to fish and wildlife will be to the aquatic environment of the receiving waters. Incorporation of tertiary treatment of wastewater can only be expected to benefit fish and other aquatic life whose life support systems are directly dependent on adequate water quality. Fish and wildlife are environmental indicators and what is good for fish and wildlife is good for people.

The treatment project itself will also impact on the fish and wildlife resource. As has already been discovered, the area can become quite attractive to waterfowl. A water supply, available food, and lack of disturbance could make treatment projects mini-game refuges. Last fall approximately 40,000 ducks and geese were observed on the Muskegon treatment area during the peak of the migration. If land treatment systems, such as this one at Muskegon, are constructed throughout the country their combined impacts could be quite significant.

While the incorporation of management techniques could benefit waterfowl, there are also problems and questions that will arise. Studies should be conducted on the effects these systems may have on waterfowl. Will they possibly pose problems by short stopping birds during their fall migrations? Will there be any danger of transmission of pathogens or toxic substance through the food chain? Will crop depredation become a problem? Concentrations of waterfowl during the hunting season can also be expected to precipitate problems. Controlled hunting may be part of the answer to the problem, since this would preclude a large build up of birds yet provide an important recreational opportunity.

Not only will treatment facilities be attractive areas for migratory wildlife; many species of wildlife common to the area will be affected by the facility.

The system of circular spray irrigation has substantial amounts of habitat edge, and again food and water are readily available. Some problems could be expected here since wildlife populations could explode within the confines of the treatment facility. Again a controlled hunting program deserves consideration.

It becomes apparent that there will be a tremendous potential for multiple use planning for wastewater management projects. This type of benefit has been realized at Woodland, California, where land is leased for agriculture in the summer and for duck hunting in the fall.

Ironically some of the benefits the facility may have to fish and wildlife may also create problems for utilization of the resource. The construction of numerous facilities of this kind may benefit the resource base (that is, increase in total wildlife numbers) but at the same time, decrease its availability to the sportsman. The elimination of hunting on thousands of acres which could be utilized for wastewater management will result in increased pressure on already overcrowded public hunting areas. This is a problem which would be of great concern to Fish and Wildlife Managers.

From an ecological standpoint, the spray irrigation method of wastewater management promises to be one of the better systems yet undertaken. However, there are environmental costs and problems associated with facility construction and operation. The large acreage required for the irrigation rigs must be cleared; service road construction as well as the installation of drains and collection pipes requires further habitat disruptions. Wildlife habitat is also lost in areas required for lagoon construction. The wildlife dependent on the habitat removed will probably be lost, assuming that adjacent lands are at their maximum carrying capacity.

Mitigation of habitat loss might be achieved by providing wildlife food patches and cover areas to replace the habitat destroyed during project construction. Plants selected should serve a variety of wildlife needs and, of course, be suitable for use in the specific soil and climate of the area. Lands adjoining the irrigation areas could be managed for wildlife. The benefits of habitat interspersion should be easily achieved on these sites.

In summary, our agency commends the efforts here at Muskegon. We believe that improvement of water quality is paramount to the protection and enhancement of our nation's fish and wildlife resource. Wastewater management systems, such as the one here at Muskegon, offer potential for fish and wildlife management and enhancement; however, they also pose ecological and sociological problems. Additional study and monitoring is needed to more adequately describe these problems, but it appears that with proper planning multiple use objectives can be realized.

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Dr. Howard Tanner*

As frequently happens when appearing late on a program you find many of the remarks you have chosen to make have already been made. I find especially that Mr. Belford Seabrook expressed many of my thoughts in substantial detail. I can only offer that I speak from a different perspective and therefore you can judge both of us in somewhat different contexts.

It is usually customary to make a certain number of disclaimers and admissions of bias and so forth. Since you are aware of most of mine anyway, I would choose to make them rather than have them extracted from me. I have, as a part of my approach to an evaluation of reuse and recycling systems such as the Muskegon one, a background as a fisheries biologist and a longstanding belief that you "don't just put it in the creek". I have some eight years experience with the Michigan State experimental sewage effluent recycling project where I was clearly and strongly an advocate of a similar system. Now I come to you as a state bureaucrat with other responsibilities. Those are the admissions I feel compelled to make.

I would offer some general comments. First, reuse and nondisposal concepts (added to the project's design, management, and maintenance) are obviously much broader than the simple one of water and sewage treatment as we usually see it. These reuse and nondisposal concepts, however, certainly are an appropriate way of the future.

I find that much of the rigor of judgment and critiques being applied to the Muskegon project and similar projects are not in a similar way applied to the more traditional alternatives of sewage treatment. I ask, as we evaluate this project, that it always be placed in clear relationship to other alternatives. I believe, in addition to the traditional cost benefit ration, that the increasing cost of energy should be recognized, and that we view all sewage treatment approaches in terms of energy resource costs. I am convinced that reuse systems of all kinds will have more favorable cost benefits in light of today's increasing energy costs. I would hope, in reviewing the Muskegon project, that goals would be stated and restated (e.g. of research, demonstration, management, and socio-economic impact) and that we keep these goals well in mind.

I apologize for offering comments with not having been here for the full program, nor am I able to stay for the rest of the program. However, I have yet to hear any comments concerning calculation of what I call a mass balance. Certainly now or soon you should be able to speak in terms of quantities, in terms of quantities out and quantities retained. Then when you say out, you should be able to document what you mean by out, in terms of values and problems, if any, the out flowing materials are creating.

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Something that I find disturbing and maybe unavoidable, although I hope not, is the concept that every such site has a finite life expectancy. I really believe that we should have as our goal management of the site to preserve its useability in food production in perpetuity and that any less ambitious goal is unappropriate. Not only should we preserve it, we should calculate how to enhance it. I sometimes see that missing or contradicted. I think that we ought to make enhancement and perpetual useability of the land for production a more clearly stated part of the Muskegon project. We speak of ourselves as ingenious people and, I presume on the basis of record, maybe we are. I personally believe that we do have significant ingenuity and many ingenious ideas.

One element that is required as you look at an opportunity to apply your ingenuity is the element of control. Once control is lost, once "it" trickles out the end of the last pipe, I don't care how ingenious you are, you simply have no longer any opportunities. One thing that the Muskegon Project does is to establish a measure of control on the wastewater over a longer period of time than in more conventional treatment systems. This control is essential in any designing of new and ingenious ways to bring about the reconversion of waste back into productive systems.

We must logically expect that certain materials, previously allowed in particular waste streams, are going to have to be reduced and/or excluded. Recognizing that in this waste stream, reuse is dependent upon biological activity, those materials that would inhibit biological activity will be those eliminated or reduced. I expect that these materials will be identified and controlled, resulting perhaps in a change in habits of industry and housewives. I suggest that heavy metals and boron are examples of materials that will have to be lowered before being accepted by the treatment system.

I was asked to respond in some way to how the Muskegon System and other very large land "consumptive users" would be received by the State Department of Natural Resources. I must respond to that question with other questions. For example, if we take a system of a number of acres, 500 to 1,000, 10,000 or whatever, and begin to use it as a site for application of wastewater, what other uses will remain permissable? Production of food? What about recreation, hiking, and mushroom picking? What about hunting rabbits, deer, pheasants, and migratory waterfowl? If you ask my agency how can such systems be fitted onto public land, I must immediately come back with those kinds of questions. If you want 500 acres of the Allegan State Forest, we have to know what other uses will be displaced or not displaced. Another speaker earlier spoke to the desirability of establishing a land treatment system where we can use private lands. Under the proper circumstances farmers would not have to yield their land into public ownership and yet receive wastewater nutrients and water. I would wholeheartedly concur.

I share the observation that a lot of speculative opposition to land treatment has developed based on a lack of information. I understand that a substantial argument existed within my agency and within Public Health about the production of minnows in sewage lagoons, about whether or not as a state agency we ought to be moving minnows from the sewage lagoons to a state fish hatchery for consumption by muskies, which would be released in the public waters in two or three years and later caught by members of the public. I am not an M.D., but I suggest most respectfully that that is stretching it quite a long way in expressing concern for public welfare.

When we look at what we may or what we can permanently allow in terms of the use of products produced from these kinds of systems, it always hinges on the question of viruses. Heavy metals, persistent organics, and other concerns may also occasionally be expressed. When they question how other users may use an area, again the question of virus seems to be paramount. When we talk about ownership, whether land must be acquired by the state agency, municipality, or the county, or whether it might conceivably remain under private ownership, again the question of viruses strikes very hard. The cost of the project in terms of the size and buffer zone, i.e., the amount of buffer that has to be acquired, again appears to hinge upon a concern about the transmission of viruses. There are instances where I would like to be permissive. I am constrained by the lack of information on what was reasonable in terms of protection of people from viruses. I have, at this meeting and at others, heard very, very little about the development of additional information on the potential for virus transmission in such systems. I urge that you hit that subject and hit it hard.

I would offer some observations pertinent to the review of proposed conventional wastewater treatment systems relative to land treatment systems like Muskegon's. I continue to see a substantial dependence upon chlorine. My friends in the field of virology point out repeatedly that there is substantial evidence that chlorination, as presently practiced in traditional sewage treatment systems, is not effective in the elimination of viruses.

I would make the observation that most engineering design consultants are locked into traditional technology. I don't condemn them for this. I merely make the observation that they are locked into the conventional system by their experience and by the training of people that they have hired. They are directing the choices for form of treatment from senior positions and also obviously by profit motives. They are afraid that new experiences might plunge us into solutions with strange new areas of competence, and in the unfamiliar situation the opportunity to make mistakes and lose money would develop. I don't know what to do about this, but I feel that I have to make this observation. Again, going back, I admit that this point has been made by others; I merely restate it.

We have much to gain in terms of public acceptance. But many of the problems that we face are not technical. They are not biological. They are not engineering. They are not mathematical. They are social. They are political. They are economic. Some of them are psychological. This question of land ownership: If you are going to really see a proliferation of land treatment systems, we have to develop opportunities for leaving land in agriculture and in private ownership. The past experience of the Corps of Engineers in the Thumb Area of Michigan was in my opinion condemned to failure from the start by the suggestion that the most productive lands that we know in the state of Michigan would have to be acquired by the City of Detroit.

In working down now to a close I implore that you don't let us still be crying in the wilderness of the unknown a few years from now. Make sure we do learn by this experience, but don't freeze the model. This Muskegon model is a good model, but each system, each set of soils, each set of people, each set of opportunities is going to require a specific fit. Grasp the concept, not the model. Grasp the concept of biologically reincorporating these materials back into the productive and profitable biological systems that we now manage.

I am sure that as we begin to maximize these systems, the Muskegon system and others like it, that we will see the incorporation of solar or waste heat from industry and production of electricity. I recognize that Michigan receives solar energy of a rather low grade variety. It is not an Arizona or Southern California variety of solar energy. There aren't very many engineering and mechanical systems that are capable of using this low grade kind of solar energy productively. A biological system, however, needs to receive only a ten degree rise in heat to double its productive rate.

It is disturbing to me that as an Agency Head I have been able to do little or nothing about furthering recycling systems. There has been very substantial pressure in our State Legislature from the Governor, etc., to approach full speed ahead with sewage construction grant programs as a billion and a half dollar construction effort. I understand that and accept it, but nevertheless, I have to bemoan that this hurried application, this hurried speed-up of projects leaves almost no room for opting for new and nonconventional systems. The only way we can move this rapidly is to lift off the shelf existing plans and concepts and translate those into the construction schedule. I don't say that there is anything that we can do about it. I recognize it as an opportunity that we have lost. We did not have the design criteria to do otherwise. I want, as head of the DNR, to have Michigan be in the lead in every appropriate instance toward resource reuse.

I would close by saying that I pledge to you that we will do the best we can to make whatever constraints we must apply most reasonable, to be most generous and still consistent with prudent behavior and public protection. I hope that Muskegon will provide many of these answers. I thank you very much.

MICHIGAN DEPARTMENT OF AGRICULTURE

Donald Isleib*

The Michigan Department of Agriculture views the advent of projects like the Muskegon project from our perspective of advocate for two separate and different groups of people of the state. We have a major role in consumer protection. Three-quarters of our budget and people are devoted entirely to the business of protecting the public food supply. We additionally have a responsibility to stimulate and nurture the practice of agriculture in our state, to encourage and stimulate the business and success of food producers in any way that we can. There has been a great deal said very recently about the divergent points of view of these two groups, consumers and food producers, which would seem to put them at odds. We feel that we don't have to enter that argument in Michigan.

We are a food deficit state, in terms of the adequacy of what we produce in Michigan to feed Michigan consumers. We are about 50 percent food deficit. Therefore we feel that we can be effective advocates for both consumers and producers, especially in view of their mutual dependency.

We are a regulatory agency. We have very strong ties to the Food and Drug Administration and the USDA in terms of our consumer protection activities.

We are authorized by federal and state law to be the agency which regulates the quality of dairy products entirely. We are subject to surveys conducted by federal agencies to insure that we perform adequately, but we bear responsibility for regulating this industry in its entirety. In the area of meat inspection, we share the activity with USDA. This includes assurance of sanitation of the establishments which convert live animals to meat, and in the analysis of meat and meat products themselves to see that they are clean and wholesome as offered to the consumer. In the area of fresh and processed fruits and vegetables, we have a major effort in being sure that these are up to the standards which are largely prescribed by federal agencies.

Michigan law requires that this agency adopt the standards that are set by FDA, EPA and the other federal regulatory agencies for residues, contaminants, and whatever else may occur in foods, such as preservatives, colors, food additives of any kind, whether advertent or inadvertent. The only exceptions to these standards are if we have clear evidence, based on our judgment as to its technical acceptability, of a need for different than federal standards. Our experience has been that we can adopt only more protective standards and not less protective standards. We are not really well equipped to develop standards different from those of the federal government. We have largely refrained from doing so except under mandate of one sort or another.

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I might point out that it is very important that we identify the difference between designed additions of materials to food and incidental additions of materials to food. In the case of designed additions, there is a great body of evidence which is assembled by the Food and Drug Administration or the EPA, depending on the nature of the additive to food. A more immediate problem and one certainly more difficult to deal with, is the occurrence of accidental or environmental additions; those that occur in food not by design but by accident. They may be environmental features, contaminants, or naturally occurring elements which are simply entrained in the whole process of food production. They may be industrial or man-made chemicals, or pesticides, or any one of an array of materials which can be identified in food and for which there may or not ever have been an appropriate testing procedure to determine the acceptability of a given level of residue in food. I say this because it seems that the things that have been most difficult for us as a regulatory agency and for the public as informed consumers to accept are those inadvertent additions.

It would seem that when we talk about recycling or regeneration of resources, we think in terms of food produced in a system like Muskegon's, which implicitly may be something less than absolutely pure.

The agriculture environment is not an aseptic environment. It is not a totally sanitary environment. It certainly does not have the capability to exclude any element at will which one might hope or choose would not appear in food.

The contaminants that give us trouble and earn the characterization of chair-bound bureaucrats, who are intransigent from moving from pre-adopted positions, are those things that appear in food inadvertently. Nobody knows what the consequences of these contaminants may be, although at times the public has a pre-conceived idea as to what the consequences might be. Whether that public is well-informed, or influenced by an opinionated minority, we do have to cope with the problem of how to rationalize our confidence that the occurrence of a contaminant in food at regulatory levels adopted on the basis of informed opinion is not contrary to the public interest.

Therefore I hope that the designers and operators of this system and others like it will share with us the obligation to acquire the evidence necessary for conscientious regulatory performance.

Until now we have had to extrapolate, interpolate, extend and do all kinds of things which I think are rather innovative, to establish techniques of contaminant surveillance in food production. In the future, we are going to have to obtain more data as the basis for significant decisions.

By way of explanation for those of you who are visiting us here today and are not Michigan residents, we have a kind of unique site up in one of our mid-northern counties, a graveyard. It wasn't there a year ago. It is presently 40 acres in extent. Its occupants are 22 or 25 thousand dairy and beef animals that have been destroyed because they were contaminated with an industrial chemical that inadvertently got into the food chain. That doesn't include the million and a half chickens destroyed or the 25,000 animals that are still standing alive on Michigan farms which are also known to be contaminated.

The controversy that this kind of experience creates in the public mind (in those who are asked to accept somewhat arbitrary although basically well-founded conclusions) as to the acceptability of any contaminant in their food, boggles the mind. It appears likely that our decisions will be adjudicated in court, in every kind of court, the court of public opinion as well as the various circuit and appellate courts in the state.

In contrast to this recent experience, we do hope that we can generate information that will help us to establish that the products produced from the agriculture endeavor on sites such as this one at Muskegon are acceptable. We need knowledge not only related to crops, but also to animal products produced from these crops.

We know, of course, that fat soluble contaminants tend to accumulate in animals even though they may be present at very, very low levels that are totally innocuous in feed. The case in point is last year's experience. Other experience with chlorinated fat soluble pesticides and other industrial compounds is replete.

I might point out that our regulatory philosophy, which we share with the federal food regulators, is that food has to be acceptable at its point of origin. We share this with our pollution control and waste treatment friends who have adopted the idea that dilution cannot be used as the answer to pollution. We cannot make clean grain out of rat feces-infested grain by mixing it with other clean grain. We cannot make clean milk out of contaminated milk by diluting it with clean milk. We have to apply the criteria that we apply at the point of origin of food.

I have no qualms that the acceptability of agricultural products from the Muskegon system can be demonstrated. This system represents a very refreshing and appropriate application of resource management. In our role as regulators and stimulators of agriculture we are excited about the prospect that society's waste can be a resource with utility to the farm community. I share with Dr. Tanner the hope that lessons learned here, and data accumulated here can be extended so that it need not apply only to lands in the public domain and owned by the public for this single purpose. That perhaps with appropriate insights and technology and appropriate guidelines for utilization, private individuals may also share in the utilization of this resource. We have done some surveying in our department with a view toward assembling the information necessary to support progress in this direction.

As I mentioned earlier, the Michigan Department of Agriculture is a regulatory agency, and we don't have any budget appropriated for any research function. If we need to know the answer to some question we conduct a survey, and sometimes the surveys are imaginative to the point of bordering on research. As an illustration, we have conducted surveys of both elemental and organic chemical contaminants in food. This includes crops and animal products produced where waste discharges have been involved.

We expect to keep ourselves informed and we expect to contribute to the accumulation of these data. We do have good analytical capabilities. Because of our need to know we think it appropriate that we participate as surveyors. We certainly expect at some future date to respond to inquiries which will be directed to us regarding the quality of food produced on a site like this, because we have the role of food regulation in the state.

Despite our philosophical confidence in the quality of crops from such sites, I think that we do need those critical books of data, at least to confirm our judgment. In our experience, at least some of the public is very jaundiced about putting its faith in the judgments of its employees. I hope that we can merit their approval of our regulatory decisions.

I can tell you that the staff of our department is as eager as anybody to see this and counterpart systems succeed and be adopted in their appropriate variations by other communities in other locations. We will help to achieve this success as our resources permit us to be involved. We can't play a lead role, but we will certainly help. I really don't think that there is anything more than that I can say, except that if there are any questions, I will be glad to answer them.

U.S. ARMY CORPS OF ENGINEERS

Lt. Colonel Donald Morelli*

I will address the Corps' interest in the Muskegon project, but first let me try to position myself and the people that are with me today in our structure so that you can have that for future reference. The Civil Works Director, the Chief of Engineers, and the Corps of Engineers have been traditionally the Directorate which was involved in navigation and flood control throughout the navigable waters of the United States, and that has been their historical role. I think you are all in one way or another familiar with that.

The interest of the Directorate in the Muskegon project is an indication of the change in that historical role which is taking place in the Corps of Engineers. The biggest division within that Directorate is the Planning Division. I am the Assistant Chief of that Division, and I might add the only military officer. It is a recently created position, although there was a previous one, a Lt. Colonel Tom Sands and before him a Lt. Colonel Dan Ludwig; I have inherited their jobs as part of the job that I have. So now you know where I fit. I am the primary coordinator for the Urban Studies Program, which some of you are aware of.

The Engineering Division is a sister division in that Directorate. A part of the Engineering Division is the Engineering Management and Urban Studies Branch, which is interested in the technical aspects of the kind of work done here at Muskegon. Mr. Noel Urban, appropriately named, for urban studies interest, is here and if you have any technical questions, he can answer them. With him is Lt. Bob Bastian, who is the land treatment man in his office and Dr. Harlan McKim from the Cold Regions Research Laboratory in New Hampshire. Dr. McKim is the program director for all the research and development money for land treatment in the Corps of Engineers.

There are three places where we are interested in the Muskegon project: Firstly, as you know, we run our own Army posts and installations. We are looking at this system as a model for an inexpensive way to do the land treatment on our Army posts. Secondly, we have application for a Muskegon type system in the recreation areas which are run by the Corps at the many Corps recreation facilities around the United States. We have also been called in the past, the polluters of local environments. We wish to stop that. Thirdly, we need information on land treatment in our Urban Studies Program. You may not be familiar with this Urban Studies Program. In 1971, at the direction of Congress, we looked at the possibility of land treatment in six areas of the United States. These were called Wastewater Pilot Studies. We have finished all six and they are presently in my office being put together to send forward to Congress. Then they will also be sent to the governors of the states involved for their use.

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Our Urban Studies Program evolved from the formation of the Wastewater Pilot Studies in 1972. We recognized there was more to an urban area than just its wastewater management. This was the most significant problem at the time and to a great extent still is. Our Urban Studies consider flood control, flood plain management, wastewater management, water supply, harbor and waterway development, beach and channel stabilization, lake protection, and recreation.

The most significant thing to me on my visit here was covered in the introduction. As a soldier I am accustomed to the philosophy of a hero. I didn't think I would find any heroes when I came to Muskegon, but I sure did. The people who got this project off the ground, the political, governmental and commercial and community people who put it together are, in fact, heroes. I am very interested in how that took place.

Our District Engineers in the Urban Studies Program are supposed to be the catalysts that bring together all these diverse organizations and groups in any urban area to achieve the same kind of results for all these things I just listed in one comprehensive program within three years. I think aside from the technical aspects of the project, I am vitally interested in the people who were the heroes here. How they came about putting all these diverse interests together. I plan to take some of their experiences back and have our Institute of Water Resources look into that a little more.

I will end with that, and thank you very much for inviting me. If you have any questions, the other gentlemen, whom I mentioned, will be here and they can help you out. Thank you very much.

FOOD AND DRUG ADMINISTRATION

George L. Braude*

The Food and Drug Administration has responsibility for the safety of food and for the protection of the human and animal food chain from contamination. The Bureau of Foods of this agency and the Technology Office I belong to are both regulatory and research oriented. As Don Isleib has stated, the FDA conducts surveys on dietary intakes and contaminants in our diets, and may establish rules, regulations, or tolerance for contaminants, including the ones potentially derived from the use of sludge on land. A number of potential problem areas can be visualized for an operation such as Muskegon's, and I would like to summarize my thinking regarding each one of these areas.

First, there are the heavy metals, a widely publicized issue. My own belief is that the heavy metal problem may be much more acute where sewage sludge is used, as opposed to a Muskegon effluent/wastewater type of situation. For one thing, cadmium levels in the Muskegon sewage are relatively low. In addition, a given amount of contaminant is spread over a much larger land area than normally used for sludge application, so that fewer pounds per acre are applied. The potential for plant uptake and food chain contamination is thus reduced. There are, of course, circumstances such as high pollution areas, or cities in which cadmium, lead or some other metal may be a problem. In addition, difficulties may be experienced when sludge, which has accumulated in holding basins, is applied to land, and on a much smaller acreage than is practiced with wastewater.

The Food and Drug Administration is conducting a number of surveys on the dietary intakes of adults and selected population groups. This includes the well-known Market Basket Surveys, as well as other surveys orientated towards specific heavy metals or pesticides. The latest survey shows that the cadmium intake of the average adult in the U.S. is about 70 micrograms per day. This is just about the same quantity which the World Health Organization (WHO) has designated as the maximum safe dietary intake of cadmium. (WHO has provided weekly intake limits, which I have converted to a daily basis for comparison). We have no knowledge of the effects on people who do not have average dietary habits or cadmium intakes, or are old, very young or ill. For this reason, the agency is concerned about any increase in cadmium levels in the food chain. As stated, hazards from land application are largely related to sludge, but in planning wastewater systems such as Muskegon's and those in other areas, cadmium uptake by crops must be considered.

Lead in the U.S. diet is also approaching a critical level and an increase, especially for infants, would be of concern. There is relatively good evidence that when this metal is applied to land with sludge which is high in phosphorus and/or sulfide, plants do not take up lead through their root systems and translocate it to edible parts. However, direct physical contamination of crops and ingestion by grazing animals is of definite concern. We are also interested in dietary intakes of mercury, arsenic and selenium, but little is known about the effects of use of sewage containing these metals on the food chain.

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The other area of interest and concern is microbiology. I am not knowledgeable in this field, but FDA microbiologists feel that the use of any form of sewage on crops in the human and animal food chains could cause problems, and that care has to be exercised in the pretreatment of sewage and in its use. For a situation such as Muskegon's, the degree of aeration and residence time of the sewage are important parameters. So is the potential problem of the by-passing or short circuiting of treatment systems. The degree of chlorination, and its effects on the survival of pathogens, especially viruses, is another area of interest and concern.

Ascaris ova, or worm eggs, are known to survive for years on land, with life expectancies ranging up to seven years, according to the literature. Many people, especially in foreign countries, have contracted the disease which has then spread throughout an area. There are indications that ascaris ova are also prevalent in many U.S. sewages, and I don't think that the U.S. population would tolerate being exposed to these pathogens in their foods.

Other pathogens such as salmonella are also known to be prevalent in sewage, as are T.B. and a variety of viruses. Contamination of the food chain by any of these materials could be a real hazard. This is the reason our microbiologists feel that, where sewage and sludge are applied to land, crops which are eaten raw should not be grown for at least 3 years after the last application. Crops which would be cooked, but which would be taken raw into the kitchen, and placed on a kitchen table cutting board, etc., may also result in contamination of, say, bread or salads. These are some of the guidelines which have been under consideration. Admittedly, there is only limited information on the direct correlation between sewage-borne contaminants and food-borne diseases, which may be partly due to the difficulty of epidemiological studies in this area.

Another major type of contaminant is widely distributed and perhaps more prevalent in Muskegon sewage than in some other areas. These are industrial and environmental organic pollutants or contaminants. It is my understanding that about 60% of the flow for the Muskegon project comes from industrial sources. It is also established that plant effluents are usually monitored for such things as BOD, COD, suspended solids, etc. Very rarely have these plant effluents been analyzed or monitored for specific organic compounds, which may or may not be harmful or toxic, and which may or may not accumulate in the human and animal food chains. Examples are, for instance, the chlorinated phenols, chlorinated benzenes, polychlorinated biphenyls and similar materials. These may go through industrial and municipal sewage treatment systems largely unchanged, or only partly modified, and may be taken up and contaminate the food chain.

In some instances, these materials are formed during chlorination within a plant, such as in a paper mill, or of the effluent. Our primary concern in this area will be for direct physical contamination of crops, to which the sewage would be applied, and for domestic animals, especially cattle, which are allowed to graze on pastures or fed fodder contaminated with these materials. Potential accumulation and biomagnification in the fatty tissues of animals appear probable.

A joint project sponsored by the Food and Drug Administration and the Environmental Protection Agency deals with these issues. It involves the analysis of tissues of cattle which were allowed to graze on pastures treated with Denver sewage sludge for several years. Studies will involve heavy metals as well as organic contaminants.

A major difficulty in attempting to define what type of organic material gets into the food chain is that analytical methodology which is normally used to detect known contaminants may not be directly applicable, and would have to be modified to determine the presence of some of the other contaminants. This is especially so if we are talking about slightly water-soluble substances, though such materials have less potential for being biomagnified in fatty tissues of animals than less water-soluble compounds. Nevertheless, it may require sophisticated techniques to find and identify these chemicals, some of which may be carcinogenic.

In summary, the risks and hazards involved in use of sewage on land and crops in the human food chain have to remain a continuing concern. Starting with the planning phase and continuing through the day-by-day operation of the system, persons responsible should be aware of the hazards and conduct operations in such ways as to minimize risks. To achieve this, the system has to be operating properly to prevent microbiological and other contamination. In addition, crop selection is of primary importance. Field corn, for instance, is a good example of a relatively desirable crop, provided the grain obtained is properly processed. With overhead sprays, such as in Muskegon, there is the potential of direct physical contamination, especially microbiological. The drying of corn at elevated temperatures seems to be a desirable way of killing pathogens present, provided the temperature and times are selected properly. The other extreme, of course, would be to attempt to use crops such as strawberries, or leafy vegetables such as lettuce, where we know that serious microbiological contamination will result, and the potential for direct chemical contamination to enter the food chain is also quite real. The non-leafy vegetables are probably in the middle, but are also considered to be an unacceptable risk at this time. So the answer is to conduct operations and select those parameters which will make the system a real asset, and not a potential hazard.

CRITIQUES

TREATMENT PERFORMANCE AND ECONOMICS

Charles E. Pound*

As I traveled over the site this morning, and as I heard the speakers yesterday, I am duly impressed with the immensity of this program, size of the project, and the effort that went into making it a success. However, in listening to various people who have been involved in the past discuss parts of this program, I get conflicting ideas about the planning of the project. Of course, this depends upon their particular vantage point, but it results in some confusion as I've tried to evaluate the system. So with the diversity of planning concepts and a minimum of available data, some of the thoughts that I have may not be as germane as I think.

The first thing that enters my mind is, what can we use from this site in other places? As a practicing engineer, I would like to refer to this system for certain things. What can I refer to? One of the things that the states are imposing in many places is a very rigorous requirement that secondary treatment precede any type of land application. The level of preapplication treatment achieved here, at least insofar as federal definition is concerned, is not necessarily secondary treatment. Yet in this case, you are producing a usable end product and an acceptable effluent from the land treatment system. Why must we go to secondary treatment before application? I would like to see this point stressed in publications and discussions that will result from this project. Emphasize the level of preapplication treatment, the discharge quality, the fact that the method results in a usable end product, and that it is being sold on an open market. It is something that I can use, and I am sure other engineers can as they present these programs to communities around the country.

The second point involves reliability of data, such as coliform levels, etc., that are being measured from the drain tile versus the percolate above the saturated zone. Are we overly optimistic by measuring and projecting by what is happening now? Is dilution of effluent by groundwater affecting the results? It may be that by not monitoring the unsaturated zone above the groundwater we are facing the time in the near future when the effluent will deteriorate from present levels. I do not know the travel time between the most remote point where water drops and the nearest underdrain. However, with 500 feet between drains, the travel time may be months or even years. Because of the delay in travel time for percolating irrigated wastewater through soil, its unknown mixing with groundwater, the incomplete understanding of the many pollutant absorption and exchange reactions occurring in the soil, and spraying for only part of the year, it is difficult to tell when the system has come to an equilibrium at which time drainage water (effluent) quality measurements will be most meaningful.

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Coming from California, I am quite familiar with many areas that are using gravity-type irrigation systems, either by flooding or row crop. In time, with land as nearly level as you have here, and with increasing maintenance costs of spray rigs, you may find it desirable to consider some portions of this land for potential gravity systems; in other words, take out the spray system, level the land, and experiment with gravity-type systems, thus reducing power consumption. Your distribution to the soil may not be as good, but the very nature of the system means that it would be a less intensive energy consumer.

Information about the treatment in the aeration cells, settling ponds, and holding basins has been interesting. We have heard that something like 25 percent of the nitrogen is lost in aeration and settling units, and more is lost during long-term storage. From what I can understand, the long-term storage, depending on the length of storage, eventually results in very low nitrogen levels, 3 mg/l -N or less. If this is the case, are we really saying that all we need is long-term storage for nutrient removal? Or, are we saying that this phenomenon is specific to this particular site? The waste here is not necessarily comparable; in fact, is not comparable to other waste streams around the country because of the very high proportion of paper mill waste. If it is something that we can apply elsewhere, possibly to small systems where storage could suffice for nitrogen reduction down to 3 mg/l of total nitrogen, we need to know how to design a system to achieve this goal.

I realize that all the research to date is really directed toward measuring what is happening, rather than the mechanism of what is happening; this was very pointedly made yesterday. Mechanisms are still something that we should consider in terms of research, however. I may be stepping on Chuck Sorber's area of discussion, but as I understand it, the aerosol studies that were made earlier in the program were cursory in nature, and were not very conclusive in terms of the objectives set for them. This is a controversial area in which additional work should be done, either here or in similar types of systems elsewhere.

The last point that I would like to see followed up on, involves EPA's drinking water standards. They categorize organics into alcohol extractible and chloroform extractible hydrocarbons, and I did not hear the organics categorized in this manner during discussions yesterday. Rather, very specific insecticides, pesticides, and whatnot were measured, or maybe I just missed the data. As an engineer needing to design a system to conform to EPA standards, I can't necessarily utilize such specific information and translate it to another site because interest there may not include that particular insecticide or pesticide and EPA standards are in terms of broad categories. What I am really trying to say is that if information is also collected and reported on broad categories of organics, we can more easily transfer this information to other places.

With that, I will stop and let someone else have the floor. I do want to say I appreciate the opportunity to be here and to hear the various esteemed speakers who presented information, thoughts, and research efforts that either have been done or are being done here at Muskegon. I thank you very much.

Q. (Y. Ara Demirjian) Chuck, you didn't make any remarks about the economics.

R. (Charles Pound) In terms of economic comparisons, let's first look at capital costs with secondary treatment as a base. Secondary treatment usually costs about $1.0 million per mgd of design capacity excluding collection and transmission. We find this true up to something equal to or less than the 40 mgd category. Here at Muskegon, we are going beyond secondary treatment in terms of the effluent quality, because we are also achieving nitrogen, phosphorus, and heavy metals removal. In this particular case, we are looking at a cost somewhere in the neighborhood of $700,000 per mgd of treatment capacity at the time of construction. exluding collection and transmission facilities. Certainly capital cost for this type of system is less than we would normally anticipate.

Secondly let's look at operational costs with conventional treatment as a base. The operational costs are substantially less at Muskegon than we would expect for conventional types of treatment for two reasons. First, you have a simpler method of treatment than in most conventional types of treatment systems. You are not segregating sludge and handling that as a separate item which generally is an expensive operation. Second, you are running your effluent onto an agricultural site and the revenue from the crop will more than cover the cost of operation of your planting and other agricultural activities, including power for irrigation. These two things result in a lower total cost to the community per gallon of wastewater treated than we would expect with a conventional type system.

Q. Do you think you could gravity irrigate with an infiltration rate of 5 to 10 inches per hour?

R. (Charles Pound) I think you probably would have difficulty initially, because of the very low organic content in the sandy soil, i.e., very low water holding capacity of the soil. I grew up on a farm consisting of sand like that; it wasn't very good soil. In fact, it was very poor. We did, however, gravity irrigate. We didn't have furrows that were as long as you would like to see in an operation like Muskegon. The farmer before us open-cut the ditches and put a lot of water very rapidly into each furrow. We, on the other hand, rotated crops and through this method built up the organic content of the soil. Further, by plowing or discing to a depth of no more than 8 to 10 inches, we eventually formed a "plow-pan" that aided in retarding the percolation of water. We were then able to irrigate in a much more satisfactory manner but still using a ridge and furrow type of irrigation.

You have to have slopes that are probably approaching 0.4 percent in order to get the water to reach the other end. I would say that we probably couldn't go more than 600 to 660 feet, with the furrows on the sandy soils, otherwise we would have most of the water in the front end of the furrow. The reason I brought it up was because I think that after having started irrigating with a spray machine and building the soil by plowing back the organic crop residue, eventually you should build up enough organic body in the soils so as to reduce permeability and increase water holding capacity, thereby making furrow irrigation more feasible. Also furrow irrigation should reduce energy costs.

Q. In you desire to design other land treatment systems, what one or two high priority items do you need to know that you might get from Muskegon? Could you reemphasize this?

R. (Charles Pound) It is very difficult at this time to obtain detailed information about what is going on at Muskegon about operations, performance, and unit costs of operation of the system. We would like this information.

Q. Do you feel that this information about Muskegon is available? I mean, is this something that is known?

R. (Charles Pound) I think it is available. It just isn't readily available at this time. I think that effort will have to be made by someone to make this information available in a usable form. I like the concept of being able to present to a community the idea that you don't necessarily have to go to high levels of pretreatment before going to the land. The land in itself can be a treatment process, a unit process, rather than considering it as a depository for water that has already been satisfactorily treated. This information and this concept being presented in proper context across the country will be something useful to professionals in changing the minds and thinking of people. I think a lack of such information was one of the things Muskegon County and others have found as a real obstacle when trying to sell land treatment as a viable alternative in their community.

Q. (William Bauer) I think you made an important point in suggesting that there may be a possibility of going to a ridge and furrow system. I know that they did compare a number of alternatives for irrigation before settling upon the center-pivot alternative.

The basic reason for going to center pivot irrigation was probably because of savings in labor. A ridge and furrow system typically does require more labor than using the spray rigs. In a 10,000 acre banana plantation in Honduras, we recommended to the New Orleans steamship company operators that they install a fixed pipe irrigation system on 2,000 acres of land currently irrigated by ridge and furrow. Even though they were paying only $.45 an hour for laborers, it would be cheaper for them to put in a fixed pipe system at a cost of $1,000 an acre.

R. (Charles Pound) I would like to comment further on that. I am not criticizing the initial design. Had you selected a ridge and furrow design initially, you would have had to remove all of the wood debris so that you could level the land to a point where you could in fact irrigate with it. The way it stands, you certainly couldn't do that. I don't know whether you could even have irrigated very well by ridge and furrow with that sandy material, as free draining as it was at that time. You almost had to start with some other means of distributing the water initially. It may be something to look at in the future, however, as the energy and maintenance costs for operating the spray rigs increases.

Q. (William Bauer) Another reason that ridge and furrow irrigation was not selected, as you pointed out, was the difficulty in obtaining uniform application in the sandy permeable soil.

R. (Charles Pound) That is correct.

Q. You made a comment in relation to states requiring secondary pretreatment prior to the acceptability of land treatment for use by communities. Is this your impression in California and places where effluent irrigation is used extensively? What is the attitude of state agencies and communities in relation to the permissibility of various forms of pretreatment that have been given to the effluent prior to its application on land?

R. (Charles Pound) Unfortunately, California is a rather "mixed bag." In one system I am working with now, we are irrigating 2,400 acres of cropland, all of it by either flooding or by ridge and furrow irrigation. It is not sand, but a loamy soil. There are stratums of sand below it, but the upper surface is a loam. There the discharge requirements are 40 mg/l BOD and 40 mg/l suspended solids prior to application. Also included is a 50 MPN per 100 ml coliform requirement on this water before application, even for gravity application. It is not for the purpose of protecting the crop, but for the purpose of protecting the public that may enter the site. You can avoid the disinfection requirement by fencing so that the public cannot enter the site. The crops are of feed, seed, and fiber category.

Crops of higher order would require pretreatment of irrigation water to 30 and 30 mg/l BOD and suspended solids, and then to 20 and 20 mg/l BOD and suspended solids, including 23 MPN per 100 ml for coliform. You can graze dairy cattle on a pasture irrigated with that particular water, after initial drying. However, this is still a restricted use irrigation water.

If you desire to grow food crops which might be eaten raw, then there is some conflict between regulatory agencies, but the State Health Department recommends secondary treatment (a well oxidized effluent), coagulation, filtration, and disinfection to 2.2 MPN/100 ml before the water can be used for irrigation.

Q. But is there any consideration of a system as a treatment system itself versus just irrigation of water with minimum standards for irrigation?

R. (Charles Pound) That depends on the engineer, and I think the situation there is much like it is anywhere else. Most civil engineers tend to look more favorably at conventional treatment systems because of their professional training. The irrigation systems simply offer a means of disposing of the water, particularly where communities were landlocked and they could not discharge to a continuing, all yearround stream. Sometimes, nearby surface water is an intermittent stream at best, or else it deadends in a sink. They simply cannot discharge into it. Therefore it is a matter of convenience, or of necessity really, to put it on land, and the concept of utilizing the soil as a treatment system unfortunately has not progressed too far. Thank you very much.

AGRICULTURAL ENGINEERING

G. Morgan Powell*

I would like to congratulate the Muskegon County Commissioners for their foresight, fortitude and pioneering effort that went into this project. They certainly can be proud of their system. Based on what I have seen and heard the last two days, it is my opinion that this is one of the best treatment systems in the world. To achieve high quality renovated wastewater and do it cost effectively is quite an accomplishment.

I wrote down some of the things concerning the system that I thought were important. Chuck Pound and I have discussed the various aspects of the system over the last 24 hours. To avoid duplication, I will confine my remarks to the land application portion of the system and the soil-plant system.

My first comment is a summary of my understanding of costs. Starting with effluent out of the storage lagoons, the irrigated farm/land treatment part of the system cost the County about $800,000. The $800,000 cost included $340,000 for farm operations; $80,000 for farm equipment; $150,000 for operations, maintenance, and power for irrigation systems; and $230,000 for repayment of 25% of costs of land, irrigation system and drainage system (25% of $2.55 million at 6.5% for 20 years). That cost does not consider the 75% grant money. It is important to realize that the additional cost for repaying the 75% grant share of construction would have to be added to obtain a more accurate picture of cost to society.

Dr. Demirjian gave figures yesterday, indicating an expected return from crop sales of $500,000 to $900,000 per year for this year. (Editor's note: Actual 1975 return was about $700,000) I would expect in the future that they may well exceed a million dollars for a return. Therefore, the irrigated farm/land treatment part of the system may be a net moneymaker while simultaneously providing additional treatment to the wastewater. I think cost effectiveness is something that we've got to continue to look at in the future.

My next comment regards sampling to determine the effectiveness of the soil-plant system. I would like to see an accurate picture of what is happening. Chuck has already mentioned that he would highly recommend that you use a method of extracting the unsaturated soil water by the use of interception lysimeters. Dr. Erickson, I believe, also mentioned this yesterday. I recommend use of this method to measure the percolate as it passes beneath the root zone but before it reaches the groundwater.

Sampling water in the drain, to determine treatment effectiveness, can be misleading. This drainage water consists only partly of effluent percolating through adjacent soil. Percolated effluent that reaches the groundwater at a point midway between two lateral drains, must travel a sweeping flow path much longer than the 250 feet straight line distance to reach the drains. Following this flow path may take several years. The actual time depends upon the depth of the water bearing material and the recharge rate. The drainage water then will not be representative of the equilibrium treatment condition and certainly will not accurately reflect seasonal or even annual changes.

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Supporting evidence that the drainage water quality does not reflect treatment from applied effluent is that its chloride content is less than one-half of the content of wastewater applied to the surface. Since chlorides have very little interaction with the soil-plant system, what we are getting out of the drain really is groundwater from the site diluted with some percolated effluent. While I suppose that the non-application of wastewater in winter with its four months of winter precipitation would tend to perpetrate some dilution, it seems unlikely that the present 2 to 1 dilution will continue. Measurement of the percolate from the unsaturated zone just above the water table is a much more direct method of determining the actual treatment occurring. I believe that predicting expected future treatment based on lysimeter data will prove more reliable than predictions based on drain water quality.

Another reason for measuring the quality of water flowing in the unsaturated zone with lysimeters is that it can give a fairly accurate picture of the effectiveness of treatment on a daily or weekly basis. It can be an operational tool. Used properly I think it could be a tremendous aid in scheduling the application of water and fertilizer on a daily or weekly basis.

In addition to the need to establish a mass balance for BOD and other parameters, mentioned by Chuck, we need a mass balance for water and nutrients. We need to know what is happening to these parameters, where the sinks are, and what change occurs in the lagoons, treatment cells, soil profiles, etc. We need to do more to quantify the apparent significant diluting effect of high quality groundwater inflows to the drain system laterally from around the site or upward from a deeper aquifer.

We need to know more about the dynamics of nitrogen utilization, retention, and release in the soil. If nitrogen is being removed and stored in the soil profile now, then over a long time period the rate of storage is going to decline. It will eventually reach a steady state situation where the nitrogen "in" is equal to the nitrogen "out" with little change in storage. We need to know if this is occurring so that early measurements of treatment will not give us misleading data for long term operations.

I recall that in the early stages of the Flushing Meadows project a 70% nitrogen removal was reported. Apparently they were getting tremendous storage of nitrogen in the soil profile. After the project had been in operation several years and it had reached a steady state condition, the nitrogen removal efficiency dropped to about 30%. This was a significant change in nitrogen removal, and data from early stages would indicate nitrogen removal efficiencies more than double that possible in the long term.

You have done some experimenting with different crops at Muskegon. I would suggest that you continue and expand that work by considering crops like Christmas trees, pulp wood trees or other tree crops, forage crops (if there is a market) as well as the grain crops. All of these have applicability to land application systems. In the future other crops may be equally as good or better than corn for treatment and revenue. I have seen indications that corn may be a poor extractor of nitrogen at the low concentrations in the applied water, and other crops may be more suitable under these conditions.

There is little information available about how to design an operation plan for the land phase of wastewater treatment systems. As consulting engineers we need to know how to schedule the wastewater irrigation and fertilizer applications around the planting, tillage and harvest operations so that both wastewater renovation and utilization can be optimized. A possible study on optimizing operations was mentioned yesterday. You can't forget that it is going to rain, too, and you've got to factor that probability into the operation. All of these things need to be considered in developing an operation plan and establishing loadings for an evaluation of land application. Such an operation plan can become rather complex, and computer modeling can be helpful. A model that could be used with the proper inputs to suggest management alternatives under a wide variety of precipitation, evapotranspiration and soil conditions would be most helpful to consulting engineers.

Lastly, we need the research results. We need the published results from this project in our hands, so we can refer specifically to it. I don't intend to step on anybody's toes, or point the finger at anybody, but where are the results? The handouts that we received indicate that approximately $200,000 alone was spent on preconstruction studies. I presume that this money was for the evaluation of the center pivot irrigation machines. The irrigation rigs have been in for a year and a half. Writing the specs, getting bids, delivery and set up of equipment would have taken six months to a year. Therefore the preconstruction research must have been finished over two years ago.

As a consulting firm working with designs for land application systems we have had the need for results of the center pivot evaluation in some of our projects. The only place we can get any information is from a copy of the specs that were written as a result of the research. That doesn't tell us the results of the research itself. We need the backup data to determine applicability to other areas and form our own conclusions for establishing our designs and specifications. I would ask EPA, you put the money into it, when can we expect the results from the research projects that are being funded?

The research opportunities are fantastic; nearly unlimited for a project such as the one here at Muskegon with about 5,000 irrigated acres. Practically an unlimited water supply is available here at the site. Think how many test plots and pilot studies we could put in, with this kind of a system. You could take every scientist in the country and put them here in Muskegon. However, I don't think that we can even afford to do all the research that has been specifically mentioned here. The funding is just too limited to pour in the money that it would take to do all the research that has been mentioned at this one conference, on this one project.

Where to put our research priorities is the question. There are also other projects which have research opportunities. We must not forget that there are two other land application alternatives, infiltration/percolation and overland flow, for which we also have information needs. This need and opportunity was mentioned yesterday and I emphasize it here for your consideration. I wish we had another week to spend here, to sit down in a select group and prioritize those research needs. Unfortunately, we don't have that opportunity. We've got to figure out some way to get the best answers for the fewest dollars.

That concludes the remarks and comments that I have. I appreciate the opportunity to attend and to have been asked to comment on this system. I repeat that I think this is one of the best wastewater treatment systems in the world. Muskegon County and others who were involved with making this project a reality can be proud of that.

R. (Y.A. Demirjian): I would like to make a remark at this time about the research information. We in Muskegon so far have reported on our work every year. But this has not been in the form of a publication. It has been difficult to report on a system that really had not operated fully until this year. We are working on a publication now.

AGRICULTURAL MANAGEMENT

Leo Walsh*

I would first like to say that a day's experience here has not made me an expert in terms of land application of effluent. We have been doing some work in Wisconsin on land application of effluent, but the majority of our work has been on sludge application. As was indicated earlier, many of us are interested in land disposal systems and I very much appreciate the opportunity to visit this site and make a few general remarks and observations.

At this point in the program I find that about two-thirds of my talk has already been covered, but I will try not to repeat too much and highlight some of those things that I think need emphasis, especially some of the remarks that Dr. Powell made.

First, I would like to emphasize that this kind of demonstration-research project is not set-up in a way that we can identify very many of the underlying fundamental principles, so it is difficult to translate these results to other sites in other areas. A couple of the speakers yesterday made a point of the hazards of translating some of these experiences directly; I would like to reemphasize that.

There seems to be a lack of published information on some of the things that have gone on in this project. For example, someone indicated that they had data on the effect of rate of effluent on crop yields. Perhaps it is available somewhere, but it hasn't come to my attention. Many of us are looking at this project as the one to really demonstrate the feasibility of using irrigation systems to dispose of effluent on land. Therefore, I think we should work a little harder in terms of getting out interim reports or other published information as quickly as possible.

In terms of translating the data, we must recognize that this is a unique site. We have climatic and soil conditions and cropping opportunities here which are unique. As a result it would be difficult to directly translate these results to other areas, except to a very limited extent.

The soil characteristics are, in particular, a critical component of any kind of system such as the one we have seen in the last few days. Small differences in soil type or soil texture markedly change the infiltration rate and the percolation rate, and this in turn determines the amount of effluent that you can apply. Unless you are on the very sandy soils as we have at this site, you are going to have horrendous problems if you attempt to apply amounts of effluent which greatly exceed the amount of evapotranspiration. In fact, as you go from sandy soils to the silt loam soils typical in the Midwest, you move from the possibility of applying four or five feet of effluent annually to perhaps no more than six to ten inches; a rate that closely approximates the evapotranspiration deficit. These soil characteristics then do play a vital role in terms of the design characteristics of any site that might be chosen. Other important factors include how long a crop will grow (growing season), the evapotranspiration deficit, and other climatic factors such as rainfall frequency and distribution, temperature, etc.

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We have many different types of crops that we can consider. We could consider double cropping with winter annuals or winter perennials in some cases, followed by a regular annual crop. Also, we could consider long term perennials such as forages or trees, as Dr. Powell indicated.

We have quite different effluent characteristics at this site than we do in many other sites. From my point of view the most important of these are as follows: (1) The low nitrogen content of the effluent - most other treatment plants will produce effluent much higher in nitrogen than that used here. (2) Cation ratios will vary, depending upon the kind of water that is being used in the system and the industries that might be adding cations to the public water supply. If a lot of sodium enters the system through industry, water softeners, other sources, a salinity problem might develop. You must have an appropriate ratio between sodium and the other cations in order to prevent the development of salinity in some of our soils.

In terms of research opportunity, we certainly have some possibilities in looking at both the physical and chemical changes that occur in soils as a result of high rates of water application. Several speakers have already indicated that things like infiltration, percolation, water storage in the root zone, and salinity are factors that can be altered and likely will be altered as a result of the land application program. These are long-term considerations that would not have high immediate priority in terms of research. However, they are items that need to be considered here or elsewhere in terms of the long-term research needs for land application opportunities.

In the chemical area Dr. Ellis mentioned yesterday that effluent can influence some of the fundamental chemical properties of the soil. Two chemical properties which are extremely important are the pH and the redox potential or oxidation-reduction reactions. The pH is likely going to change in many areas. Use of hard water will, for instance, result in liming that soil. During some periods of time, reducing conditions probably occur, and with more water and with tighter soils, we will have longer periods of poor aeratiThese factors vitally influence release of nutrients, availability of nutrients to plants, and the solubility of many of the trace metals and other heavy metals. I don't see any immediate problems with these factors, however, some long-term changes may occur which may be of concern or academic interest.

In my one day's exposure to this project, I have concluded that the most pressing and immediate problems revolve around the management of the nitrogen. With nitrogen, some "trade-offs" are going to have to be made. The level of nitrogen in the water returning to the streams should be as low as possible, but at the same time the level of N in the irrigation water has to be high enough to optimize crop yield.

For those of you who aren't soil scientists, I should point out that adequate plant nutrition requires that you have a sufficient quantity of nutrients in the soil, and that you have a sufficient concentration of the nutrients in the soil solution. In other words, the water being taken up by the plant must contain an adequate concentration of the nutrient, in order to have the plant adequately supplied with the nutrient in question. Nitrogen has always been a problem because of the fact that it's quickly converted into a leachable nitrate form. On these very sandy soils, some leaching of nitrogen probably occurs, especially when irrigated with high rates of effluent. Leaching is recognized by everyone as a serious problem, but many scientists would not immediately envision low concentration of N as being a potential problem.

All of our soil test recommendations and all of our fertilizer experiments have been based on rate studies. We add differential rates of N, such as zero, 100, 200, and 400 lbs/A. We generally have had no concern about the concentration in the soil solution, because of nitrogen fertilizer rates and with the relatively low amount of water normally used, either through irrigation or precipitation, concentration is always high enough to adequately feed the plant. But when you use rates of two, three, four, or five feet of effluent over a season, you may have the concentration of N low enough to limit plant yields even though the total N applied would generally be enough to produce an optimum yield. For instance, you could apply the recommended rate of N, perhaps 100 to 150 pounds/A, in effluent but have it so diluted that the plant would literally starve for nitrogen. The plant has to expend energy in order to move nitrogen out of solution and get it into the plant root, especially when the concentration of N in solution is low. If an application of 2 acre-feet of effluent containing a relatively low amount of N results in N deficiency, it may appear that the addition of more effluent, perhaps 4 acre-feet, would improve the situation since twice as much N would be added. However, this may make it worse since the extra water may lower the amount of oxygen in the soil and keep the soil a little cooler. These two factors would actually mitigate against the uptake of that nutrient by the plant. When you have lower oxygen levels and cooler temperatures you have to have a higher concentration of nutrient in order to get it into the plant root in adequate supply. This is a problem that is going to have to be looked at more closely before you can develop a program to successfully manage the N for this system.

I think that application of N in the irrigation water has some possibilities and it should cut down on leaching losses. However, a certain minimum concentration of N in the water moving through the unsaturated zone will still be required to get an adequate supply of the N into the plant.

We have some experimental work going on at Hancock, Wisconsin, on a very sandy soil which is similar to Muskegon soils. In this study, we measure all the inputs in terms of nitrogen and irrigation waters and we determine water loss by evapotranspiration and drainage. Also, we measure all nutrient losses in the drainage water. We are trying to optimize both water use and nitrogen

HEALTH EFFECTS

Charles A. Sorber*

At the outset, I would like to commend Muskegon County and the EPA Region V for two things: First, I was here in 1971, and quite frankly, I had some doubts that the Muskegon Wastewater Treatment System would ever become fully operational. This has been my first opportunity to return to the site, and I can assure you that there have been tremendous changes which are attributable, I am sure, to the dedication of people in Muskegon County and the Region V EPA personnel. To be precise, these groups have worked very, very hard during the past four or five years for this project's success. I am sure that these dedicated people will continue this level of effort.

Secondly, I think that those same two groups of people should be commended for this meeting. It certainly has been a very informative meeting and, for some of us, it has been a very pleasurable experience, also.

I find myself in a very peculiar situation today. My charter is to critique the land disposal health effects research here at the Muskegon County System. As you probably have noticed yesterday and today, there has been little, if any, research conducted which is directly related to health effects. I will admit that some of the monitoring information that is being developed along with some of the pre-system design studies and their refinement will provide some of the answers which will be valuable in evaluating the health effects. Unfortunately, much of the early information never got used for that purpose, since the main objective was to get the system going.

In addition, and I think most importantly, when this system was designed every effort was made (within the knowledge available at that time) to minimize health effects. This might be exemplified by two things that you have seen: the nature of the spray trajectory from the center pivot rigs (which is directed downward as opposed to up or out) and the under drain system that was installed. Both of these design conditions were intended to minimize health effects from this particular project.

Some years ago my colleagues and I developed the contention that the health effects with regard to land application of wastewater could be minimized by proper site selection and proper system design, as long as the system was designed so that secondary treatment was provided and that adequate disinfection was practiced. We also pointed out that there were many facets of the problem about which there was little or no information. Although lack of information should not preclude the design and operation of spray irrigation systems, there certainly was and continues to be a requirement to conduct research on these potential problem areas. This would permit the development of data which could be used to answer many of those public health questions which will be raised. My heart was warmed yesterday, as I listened to many speakers say that we need this data now, because the public is asking these questions either in terms of lawsuits or in terms of criteria for practical application of this process.

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About a year and a half ago we developed a list of research needs as they applied to different aspects of land treatment and that list is probably just as valid today as it was then (see Tables 1-3). Unfortunately, some of the things on this list are not applicable to the Muskegon site because of the design considerations at the site. As we go over this list I will attempt to point out the areas where active research is underway.

TABLE 1. Public Health and Environmental Research Needs Related to Chemical Components of Wastewater.

The evaluation of the persistence and translocation of heavy metals in soils at wastewater land application sites.
The characterization and evaluation of the persistence and translocation of pesticides and trace organic constituents of wastewater (and their metabolites) for their potential environmental impact.
The comprehensive investigation of possible mechanisms for the removal and/or conversion of problem inorganic species, especially nitrogen, which may tend to accumulate in groundwaters.

First on this list in Table 1 is the evaluation of the persistence or translocation of heavy metals in soils at wastewater land application sites. There have been several studies on this, and it has been determined, and I think agreed to by the scientific community, that heavy metals at concentrations normally found (and there are exceptions to this rule) in liquid effluents pose no immediate problem at land application sites. By and large, the heavy metals are retained in the upper few inches of the soil. One potential problem was alluded to yesterday by George Braude as he described the possibility of cadmium and possibly zinc accumulating in the plant tissue and thereby causing long-term problems. I suspect the one unanswered question in this area (which could be adequately addressed) is this: "Is there a life expectancy to a particular site based on heavy metal application and accumulation in the upper levels of the soil?" Again, that is not an immediate problem. It is something that will develop through the monitoring programs at sufficient numbers of sites around the country.

You also heard yesterday about the characterization and evaluation of persistence and translocation of pesticides and trace organic constituents in wastewater, their metabolites and their potential environmental impact. There has been considerable work done on a limited number of pesticides. In addition, there has been a study sponsored by the Department of the Army at the University of California at Berkeley. The results of that study indicated that the selected pesticides at the normal concentrations found in wastewaters at military installations (probably higher than normally found in domestic wastewater) did not appear to pose any problem. Most of the pesticides were hydrolozed or biologically degraded rather rapidly, and they never seemed to reach the groundwater.

The question was raised yesterday about other organic constituents. It was pointed out then that some of these compounds may be carcinogens. Quite frankly, relatively little work has been done along these lines. Again, I am not too sure whether it is of immediate concern, but it is certainly something that should be considered for the long term. This work will probably develop through the ground water monitoring programs at existing sites.

Today you have heard a discussion on the investigation of the removal of inorganics, particularly nitrogen from within the soil matrix. Nitrate nitrogen and sodium movement through the soil and possibly into groundwater are important from a public health point of view. This problem is really not applicable to the Muskegon site because of the nature of the design. Contamination of the ground water is not of primary concern due to the under drainage system. I was glad to hear the data yesterday which indicated that the outlying wells seem to be improving in quality. This is probably due to the direction of flow (drainage) of some of the ground water to the collection system away from the wells. Thus, I would not anticipate any major ground water impact at the Muskegon site at least from a public health point of view.

TABLE 2. Public Health and Environmental Research Needs Related to Wildlife and Cattle

The evaluation of long range effects of land application of wastewater on plant, animal and disease vector ecology.

The evaluation of the capacity of wildlife, including migratory birds, to carry infection or infectious agents great distances from the land application site.

The evaluation of the effects of human and animal pathogens and organic and inorganic wastewater components on domestic food animals raised on feed crops at wastewater land application sites.

Another group of items explores research requirements as they relate to wildlife and cattle (see Table 2). Research on the ecological effects on animals is important but the specific need depends upon the particular site. The first two items in Table 2 are important for the long range. Projects are underway or have been initiated on this work. In the late '60's the Penn State researchers did some background work on birds and other species at their original wastewater spray irrigation site. Now they have developed a new project which will look at animal ecology on a site which has not been irrigated, but is scheduled for irrigation, I am told, at the beginning of next year. I think the potential problem with migratory birds might be a more realistic area to study here at Muskegon due to the thousands of these migratory birds attracted to the site.

The last item in Table 2 deals with evaluating how human and animal pathogens and organic and inorganic wastewater components can affect domestic food animals raised on wastewater irrigated feed crops and pastures. Fortunately, there is a considerable amount of work being done in these areas. Yesterday, Dr. George Braude described a grazing study being conducted in Denver which is partially funded by FDA. Grazing studies would not be needed at the moment at Muskegon because there is no grazing of animals. Parasites may be the biggest single potential problem if you were to graze animals on the site. On the other hand, it would be important to document the safety of the marketed grain grown here for animal feed.

TABLE 3. Public Health and Environmental Research Needs Related to Human Pathogens.

The development of sensitive, quantitative pathogen detection techniques (emphasizing viruses) for water, wastewater, soils and spray irrigation aerosols.

The evaluation of the survival, distribution and hazard of aerosolized pathogenic microorganisms disbursed by spray irrigation equipment.

The conduct of a comprehensive epidemiological investigation at a relatively large, operating wastewater land application site.

The comprehensive investigation of pathogen survival and transport in soils, with particular emphasis on viruses.

The investigation of pathogen survival on crops and other vegetation.

This last listing (Table 3) probably has generated the most interest at this and other meetings. Its area is the public health and environmental research needs relating to human pathogens. First, it is vitally important to develop sensitive quantitative pathogen detection techniques with emphasis on detecting virus in wastewater, soils and spray irrigation aerosols, and drainage water. There was mention yesterday of this "mystic" term "virus" or "virology" by one of the speakers. To be certain, environmental virology is not practiced in conventional water and wastewater bacteriologic laboratories, and I think we must recognize that the ability to quantitatively detect human viruses is very, very limited. There have been tremendous technical strides during the past five or six years, but the technology has a long way to go. For example, while the hepatitis virus is the virus of concern with regard to wastewater and water, it cannot be isolated, grown, or identified. Therefore, many researchers study model viruses like polio. This raises questions such as: "Does the model virus (most likely exogenously added) respond like indigenous viruses, particularly hepatitis?" Probably not in most cases. Obviously, there is an urgent need for work in this area. There was a surge of research in this particular area of virus detection technology in the late '60's and early '70's and, quite frankly, there is very little going on right now (in terms of money invested in it). There is some research going on, but it is primarily residual research.

The second item listed in Table 3 deals with the evaluation of survival and distribution and hazard of aerosolized pathogenic microorganisms dispersed by spray irrigation equipment. This area, I think, is probably the most important pressing problem today. The answers do not exist for some of the important questions raised. Likewise, the need for the conduct of the comprehensive epidemological investigation at a relatively large operating wastewater land application is obvious.

Now let me attempt to appraise you as to the current research activity in this area, as I understand it. First, there was an attempt here at Muskegon several years ago to define the amount of physical aerosol created by the irrigation equipment that was selected for use in the system. We found out today that this work was completed and that a report will be forthcoming. Concurrent to that (1972), the Army Medical Department initiated a project at the Brookhaven National Laboratory which was designed to define the quantity of physical aerosol generated from a variety of spray irrigation equipment. This project looked at center pivot rigs with two different kinds of nozzles, both high rise and low rise solid set systems, and the rain gun. Pressure was varied and testing was done under various meteorological conditions. The point of that research was to look at or determine which variables had the greatest impact upon the amount of physical aerosol generated. In that sense the study was limiting since the amount of physical aerosol does not consider the biological content or impact of that aerosol. The results of that study will soon be published, and sadly to say, there are people in this room who are going to remind you that I have made that statement for a year and a half. I will not make excuses for the contractor but the Army Medical Department received a draft copy of the report in April of this year.

The findings of this study indicate that there are differences in the amount of aerosol generated by different spray equipment. However, the differences are not all that great. You might be surprised to know that under most meteorological conditions the least amount of aerosol per unit volume applied was generated by the rain gun. This resulted under test conditions including high pressure, high volume, and broad distribution of water. The difference in amount of aerosol generated by the high pressure rain gun and the low solid set system (which happened to be the system that generated the most amount of aerosol per volume applied) was about one and a half to twofold.

In addition to the research on physical aerosol generation, there was another study which involved field work on the biological aspects of aerosols generated at a land disposal site under various meteorological conditions. That work was completed not too long ago and some of the results will be presented at the Water Pollution Control Federation Annual meeting in October. The report itself should be available through NTIS within a few months.

A more important development is a recent contract that has been awarded to Southwest Research Institute and is jointly funded by the Army Medical Department and EPA. Its purpose is to conduct a comprehensive epidemiological study at a spray irrigation site. The site selected for this study is Pleasonton, California. This is the study that Dr. Albert alluded to yesterday. This study is a long study; it is going to take time. Epidemiological work takes a lot of time. It is going to take at least two years before it can even begin to generate sufficient data that might be meaningful. It is a large study in the sense that it will not only consider the epidemiology of a test population and a control population, but it will attempt quantitative analysis of the wastewater and the aerosols for chemical and biological constituents. Hopefully, some kind of correlation can be developed between the physical and biological data and the epidemiological data thereby precluding epidemiological studies elsewhere. This study may cost as much as $2 million of which a million and a half to a million and three quarters will go for the epidemiology alone. This is a very expensive proposition.

I think it is also important that we know a lot more about pathogen survival and transport in soils, with viruses in particular. Sufficient information is not available regarding viruses in soils and viruses on crops and other vegetation.

As I indicated, probably the most important problem facing land application today is the aerosol problem. And lest I be accused of picking on spray irrigation alone, I can assure you that I am equally interested in aeration chambers of activated sludge plants, aerated ponds and trickling filters. I think it is critical that we have comparative information amongst various types of systems.

I think I will stop there although I could probably go on for about two more hours. I'll attempt to answer questions at this time.

Q. Why do you think there hasn't been more work on the mechanisms for detecting viruses? Is it because nobody has any ideas or what? What is the bottleneck?

R. (Charles Sorber) I think it is like so much else in the research business. You generate a need. It takes four years to get people interested. Money becomes available and the interest wanes (something is being done). The researcher gets the money and he goes to work. It may then take another three or four years for the results to trickle out. The results get out and everybody looks and says gee, yeah, we really didn't do enough. We need some more work done, so now we are back to the first phase of the cycle, generating more interest to generate more money. In the meantime, you know, the money folks have established other priorities. The same thing has happened with virus investigation. It took four years to get EPA to have enough interest to put in the big money. The researchers went to work. The results are published and voids have been recognized. Back to generating interest. After a few years researchers have finally gotten some money and Dr. Albert mentioned three studies all funded within the last nine months.

Q. (Bob Bastian) Chuck, given the conditions of a spray irrigation system on 10,000 acres or so, a highly aerated wastewater and extensive storage after which the effluent is to be chlorinated. We are only going to give you $2 to do any kind of health effects work, where are you going to spend your $2?

R. (Charles Sorber) I'd do it on the chlorination, if I understand your conditions. So you say it is going to be chlorinated.

Q. (Bob Bastian) It is being...

R. (Charles Sorber) It is not being chlorinated everywhere, Bob.

Q. (Bob Bastian) I am talking about here. Okay. I am asking where are you going to spend your $2.

R. (Charles Sorber) I'll spend my $2 on optimizing the chlorination process. Is a given count of bacteria an adequate level? Not necessarily. Chlorination is notoriously poor for some of the potential problems we have been discussing.

Q. Chuck, how much money was spent on aerosol research?

R. (Charles Sorber) About $400,000 over the last three years.

Q. How much?

R. (Charles Sorber) About $400,000 over the last three years. There is your first $2. I understand your concern. The point is that this type of work takes a lot of money. This is a real problem. In the study that is going to be undertaken at Pleasonton, California, they are raising cattle on the land and I presume they are marketing them. It would be of value to follow that meat just as far as it will go, right? Nope! I am sorry to say that the funded study did not consider this fact. It is not that the funding agencies don't care about cattle raising. They looked for a site where the project objectives could be realized. It turns out that there is catte there, but the money is such that if a cattle study were to be included, it would take a lot more money. I understand your question; my answer is that the study will not encompass that area because it was not built into the study, as much as many would like to have it included.

INDUSTRIAL WASTES AND ENERGY CONVERSION

Ralph H. Scott*

Thank you, John. I too wish to take this opportunity to thank the Muskegon County group and my fellow workers in EPA for such an excellent program. Cramming so much information into such a short time, as we have absorbed and experienced over the last day and a half, took a lot of planning. Being last on the program finds me with the same problem mentioned earlier by others. Profound observations that I jotted down yesterday relative to what was being said have largely been shot down, but not entirely. There are a few observations left.

Concerning energy conservation, I did not find much in the hand-out material or discussions here which dealt with this important subject. I certainly think that anything written covering the actual operation of this system should deal in part with energy considerations. Energy research is in this year and will be for years to come. EPA in fact has a lot of money for energy research. We are finding that energy research funds can be applied in certain of our project areas in the pulp and paper industry. Perhaps energy research funds can be applied to studies at Muskegon.

We need a true evaluation of the major costs of the Muskegon System. For example, where are the major energy costs? What may be done to reduce these costs? I am sure that anybody from any other community looking at a system such as this is going to be vitally interested. We mentioned earlier the idea of the Chinese coolie hauling night soil. As soon as we get away from very simple operations the costs are going to increase. Dr. Demirjian mentioned that a considerable cost savings was being obtained in the partial operation of two of the aeration cells to yield adequate treatment. This should be documented and receive additional study.

In listening to all that was discussed yesterday, I tried to arrive at some conclusion as to what were the real critical factors in deciding whether the project would have ultimate success. There was, of course, the initial design stage and certainly that was a significant undertaking. Evidently this was satisfactorily accomplished with the only evident problem at present appearing to be the small debris that is continually plugging the spray distribution systems. The treatment afforded is evidently sufficient. The reserve capacity of the storage system is evidently sufficient.

I would suggest perhaps, that traveling screens or a fine screen ahead of the pump stations might help alleviate the nozzle plugging problem. Such screening can be costly at the rate water is pumped at Muskegon, but in the long run such an investment may pay off as far as insuring dependable operation of the irrigation rigs.

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It seems to me that the soil chemistry, the cropping and the crop water studies, mentioned by Drs. Ellis and Erickson are important as is the ground water monitoring. Where are these studies headed? Will they be tied in with the work that the U.S. Geological Survey has been doing? It seems to me that such a tie in will be critical in deciding whether or not we get a satisfactory, acceptable output from this operation here at Muskegon.

We need to know what is happening to this water. Bill Fleck mentioned that there is both a shallow ground water aquifer and a deeper sandstone water aquifer at Muskegon. Will toxic wastewater contaminants like metals, organics, or high nitrites penetrate into this lower sandstone aquifer? If so, this type of wastewater treatment system will have an appreciable limitation.

I have been trying to point out areas of the Muskegon system in my critique that I think might have been better defined. I mentioned already the matter of water balance. We should be talking in pounds per acre or pounds per million gallons. These are common terms that are used certainly in all effluent guidelines considerations. We might as well get used to them, even though our thinking soon must be in terms of kilograms per cubic meter. In order to define anything in pounds per million gallons or pounds per thousand gallons, you have to know the water balance. I heard it mentioned here that you put a gallon on, you get a gallon out. Obviously the situation is not that simple. It is quite important, I think, to know what is being applied; the amount of evapotranspiration. What is taken off in the crop itself, and what is actually going out the underdrains? Other participants here have suggested better ways that this balance can be measured and determined and certainly, I think, those proposals should be followed.

There has been considerable mention of aerosol problems and certainly this should be considered. One thing that occurred to me while I was out on the town -- Is there room for an entomologist on this study? Is there an insect problem? Is this insect problem going to be something that other communities will be curious about? What is the drift of mosquitos and flies and pest insects that may develop in an area such as this? A small study or a more comprehensive study by an entomologist might be worthwhile.

I have heard little mention of the sewage characteristics that make up the sewage load. What is the industrial waste load? What are the types of industrial wastes? I presume, Mr. Bauer, most of this was defined at one time or another. Were the wastes characterized as to what they contained? Without having that background, it is very difficult to comment on it. Obviously, some things stand out like the chrome wastes from the tannery up at the small irrigation site. Obviously, the source of chrome can be controlled. Is it controlled? What are the restraints on the tannery as far as production of chrome wastes? It isn't necessary that the Wastewater System take everything that industry wants to throw into it.

Are there pre-treatment restraints on the industry? What knowledge does the Muskegon County Wastewater System have of what those industries are putting in the system day by day? Is there any monitoring of the industrial effluents put into the city system? These things all become important because there generally is a considerable lag in land treatment systems between the time you overload them and the time they begin to fail. You may eventually begin to face problems from high sodium. What can we do about getting rid of high sodium? Typically your pulping wastes are going to provide high sodium. Your bleaching operation is going to provide high sodium. Your chemical recovery end is going to provide high calcium and probably high magnesium. The wastes themselves contain chlorinated lignins that produce color. Right now the system is removing this color beautifully. We saw the example this morning. How long will this continue? You know, the soil is evidently acting as an exchange resin and is taking out these color bodies and pretty soon maybe it will begin to return them back as they reach saturation in the soil. You may be accumulating, at least in the heavier soils, a lot of refractory organics that currently are not moving out. This in itself can eventually have its effect.

Now seeing that pulp and paper as well as wood products are my bag, I must mention a few land treatment experiences that we do have in this industry and that may offer some information that can be useful to this project.

In the pulp and paper field, we have used irrigation for disposal of pulping, paper, and combined pulp and paper waste, as well as for disposal of condensate, and even steambath condensate from veneer plants. In the lumber industry wastes from log ponds have also been disposed of on land. You can't imagine how raunchy some log ponds can get where they prepare wood for saw mills.

Boise Cascade at Wallula, Washington, produces 8.3 million gallons of waste per day from a Kraft linerboard plant. They built a primary and a secondary system for treatment of their wastes prior to discharge to the Columbia River. They subsequently shut down the secondary system after developing a contract with an alfalfa grower and a big vegetable grower in the area to take this 8.3 million gallons per day of primary treated effluent. Boise Cascade, however, is using a 20 to 1 dilution with Columbia River water so the growers are handling something in the neighborhood of 170 million gallons a day for irrigation. They haven't quite licked the problem of what to do with this wastewater in the off season. They say that they are going to build lakes with it. I can believe that when I see it.

Oxford paper of West Carleton, Ohio, is another example of irrigation disposal of pulp and paper wastes.

The Weyerhouser Company at Springfield, Oregon, has used spray irrigation for condensate disposal when they are limited with what they can do with their aerated lagoon effluent in the summertime when the flow of the Mackenzie River is low. They lift the condensate part of the load out of the lagoon and go to condensate irrigation disposal.

Those of you in soil and crop sciences certainly should have access to

Louisiana State University's study of the International Paper Company situation at Springhill, Louisiana. That I think was a classic study for its time, that dealt with land irrigation disposal of Kraft waste.

We currently have an interesting project with Simpson Lee Paper Company at Anderson, California. The project involves an irrigation disposal system with collecting drains. Its purpose is to let their treated wastes meet the State and Federal permit requirations when discharged. They haven't been able to meet these requirements with normal secondary treatment. They are prepared now to use a 400 acre irrigation system for additional treatment of the secondary effluent when the flow in the Sacramento River lessens and requires that they reduce their loading. They are going to crop the land, and they will keep irrigating it during the growing season regardless of whether they need to, to meet the permit, in order to keep the crops growing.

In still another example, Weston Paper of Terre Haute, Indiana, has irrigated neutral sulfide wastes onto land.

Having been associated with waste disposal in the pulp and paper industry for quite a few years, I can cite a few disastrous instances of irrigation or soil disposal. I don't think we need to identify the corporations involved. In one instance a pulp mill producing sulfide wastes ordinarily disposed of them as a road binder. During a rainy season, their storage lagoon filled and there was no need for roadbinder. They found instead a very convenient gravel pit. Can you imagine pumping six or seven percent solids liquor into a gravel formation? They ended up redrilling about 30 farmers' wells in the neighborhood. They polluted that many wells. A little bit of that stuff goes a long way.

There was another instance of a mill polluting its own water supply which I thought was a classic. It is almost like having a mill put their outfall sewer above their water intake. There was quite a bit of study done on this too, sesmic surveys and all, before they began operations. Evidently the interpretation of their pre-design studies were wrong. They pumped their waste across the river into seepage lagoons and said, "Well, it is going to come back to the river." It did all right, but a lot of it came right under the riverbed and into what they found out later was a basin area that was feeding their well supply. All of the water that they used for paper production and for their drinking supply came from this well. They totally wiped it out. The last I heard, five or six years ago, was that they were still making experimental pumpings and the well was still polluted. So with those precautionary notes, I think I'll conclude.

Q. (S. Poloncsik) I'd like to open it up for a little general discussion at this point for Mr. Scott or for any of the other speakers. I might say one thing in listening to Mr. Scott about the disaster that he talked about. I think that there is something we need to guard against at Muskegon in terms of the chemical industry. I think some studies have been done on this. But I think this is an area that we need to be concerned with. You don't mix certain chemicals that might upset the land treatment operation. If you are getting used to a certain balance of chemicals, a certain amount of sodium and a certain amount of other things, and you change that balance, you know, you might wipe the whole thing out. I think Dr. Demirjian wants to comment on that.

R. (Y.A. Demirjian) You don't take all the wastes from industry as they might care to give them to you. Pretreatment may be required. We run tests for compatibility of their expected wastes with our current wastes and with the crop-soil filter. Industries that want to expand their chemical processes give us a component sample from their waste. We proportionally mix it with our wastes and do some compatibility studies. We take the proportionally mixed wastes and do a greenhouse study to see the effect on the crop-soil filter. We have used corn, alfalfa, and other test crops. As a result of our tests, we have asked them to do certain pretreatment. They are accepting this fact, and they have hired their own consulting firms to plan and install adequate pretreatment to comply with our waste acceptance levels.

Q. Mr. Scott, these disposal systems that you mentioned at Boise Cascade and Simpson-Lee; were they planned disposal systems in the classic sense, or were they intended to be land treatment systems which you call disposal?

R. (R. Scott) For the pulp and paper group I would characterize these systems mostly as disposal systems as differing from systems designed to produce a treated discharge. For example, pumping the waste liquor into the gravel pit was just poor judgment. It was a temporary solution as far as they saw it. I think probably they did discontinue dumping prior to the time that the well pollutions started to show up. As I understood it, they only used the gravel pit disposal for a week or ten days. But in that length of time, they accomplished significant pollution of the ground water supply. The mill well pollution example, I think, you could partially determine as treatment in the sense that they felt it was going to have around 300 yards of sand to pass through before it returned to the river. No doubt part of it did return to the river. There were no deep well sampling tests set up that would identify the fact that a significant amount of these wastes would go under the river into their well aquifer rather than into the river. The river was perhaps 100 yards wide at that point.

CONFERENCE SUMMARY

Clifford Risley, Jr.*

Dr. Howard Tanner in his statement made a strong point that there is intense pressure upon EPA and the states to meet legislated deadlines. These deadlines require the agencies to make commitments and get the construction grants obligated. The only way to do this in a short time is to put the construction grant money into conventional waste treatment systems. I think this should be underscored. This is what is going to keep on happening, and if we don't do the research now, ten years from now we are still going to be building conventional waste treatment systems. So, we have to take every opportunity we can to try to encourage the kind of research and development that is needed.

It would be a little redundant to go through all of the comments but I thought the critique session was especially good. The comments were excellent. I will stress a couple of them.

Charles Pound pointed out the fact that the level of treatment at Muskegon did not meet the definition of secondary treatment before being applied to the land, but as he says, it works, so why should it meet an arbitrary definition? I think that was recognition of an excellent point. He also pointed out that, or asked the question, "Are we saying that nitrogen removal is all we need, or all we need for nitrogen removal is a long-term storage?" Well, we have evidence of that kind of removal from the large lagoon at Muskegon and I think this deserves more study. It certainly is an area of research that has been recognized before. Dr. Demirjian himself would like to have more study conducted on this. I don't think the Muskegon System is "the answer" any more than any other waste treatment system is the answer to everyone's problem, but it might be the answer to problems of many communities.

Morgan Powell recommended the extraction of soil water by tensiometers to measure the nutrient content as it flows past the root zone. This technique may or may not work but it is very important to know the nutrient content and suitable sampling and study should be made. We have been wrestling with measuring what goes through individual circles because the way our under-drain is designed; we pick up the flow from several circles. Maybe we don't need to study the entire flow, but if we know what goes on at the root zone, we may well answer many of our questions.

The point made by several of our critiquers was that we need the research results. I was particularly interested and somewhat amused by Bob Bastian's comments on getting out the data, because if we have bugged the Project and the County on any one thing, it has been where the heck is the data? Give us the raw data; give us the polished data; give us the interpreted data. We want it in all forms and we haven't been getting it out in a manner satisfactory to us. While there is a lot of truth in what Bob says, that the project has really only been operating successfully a short time and it may have been difficult to get good data, I still want the data.

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Dr. Leo Walsh pointed out very effectively, I think, the question of management of nitrogen and the point on the sufficient concentration of nitrogen in the root zone. This is very perceptive. This emphasizes the point that I tried to make at the beginning of this conference, that we have been monitoring this site on treatment performance as a waste treatment system and we are trying to gather data which will have usefulness not only in this overall demonstration project, but may prove useful to others of you in your own research endeavors. We have not been studying the mechanisms of what goes on, but with a little coaching from you as to what kind of samples we ought to be collecting, what kind of exercises we ought to be making and the application of nitrogen et al, I think we can gather the data that will make understanding and extrapolation of the Muskegon experience possible. We want to try different nitrogen-crop management techniques to make the project more effective. We invite you, if you can, to further your studies along these lines. We are much interested in this kind of data. You can see a practical application to it immediately. We invite others of you to pursue this line of thinking.

Charles Sorber has been one of the most effective researchers in the health effects area in the country, in my estimation. Ever since this project began we have been talking about the need to know something about pathogen transport and virus transport. We had included in our initial plans some pathogen and virus studies at Muskegon. Dr. Sorber adequately explained why they weren't done here; there simply wasn't enough money and the priorities for doing other things seemed to loom higher than the priority to get into this area of research. Chuck went ahead through the Army and was able to get quite a lot of effort along these lines underway.

I was very interested in Dr. Sorber's list of research needs. I met with him several years back, I don't remember if it was two or three years, when he put out essentially the same list of needs, maybe not in quite the same form. But these needs were recognized by him and outlined by him a long time ago and they were recognized by people elsewhere as research items that needed to be done. As Chuck pointed out, EPA is just now beginning to pick up studies on a few of these needs. The list of needs still remains.

One thing that Dr. Sorber stimulated which he may not realize is that there are a number of people around the country, such as several people in my own office, that have picked up on this and have been working very hard to persuade the agency to put more money into this area of research. So although we aren't doing any of this health effects research, Chuck, you certainly have a lot of boosters around that are working awfully hard and who are making headway in getting research funds applied.

I was very pleased to hear you come on strong in emphasizing that it wasn't only land application of waste or spray irrigation that disturbed you, but you were disturbed about the aerosols from aeration basins, from trickling filters and the like, because we have been hitting this one especially hard. This has been a real problem in the Chicago area. It has already resulted in the decision that caused the Northshore Sanitary District to cover their plant. They probably spent somewhere around $20 to $30 million of extra costs in covering a waste treatment plant simply because no one could prove whether there was or was not a health hazard from this.

We are now in the same situation with a new plant at O'Hare Field. The communities sued both the EPA and the Metropolitan Sanitary District of Chicago because they couldn't prove that there was or was not a potential health hazard from this new plant. The sanitary district may well find itself forced to spend something around $30 million to cover that plant and yet we can't get $5 million worth of research money to find out the answers to these questions. If we can answer them with $5 million, we think we can get a good start. But why do we allow the expenditure of construction grants funds, perhaps unnecessarily in the order of $30 million that have been expended to cover waste treatment plants, rather than spending the $5 million on research to get the answers to whether or not it is needed? If we take the assumption that the research is going to say that it is needed and then we will spend the $30 million to cover the plant anyway, then I suggest another situation. If every biological waste treatment plant, every trickling filter, every aeration basin has to be covered, then the cost of this is something other than what we had considered to be the cost of biological waste treatment, then maybe it is not the viable way to go. This may make land treatment even more the way to go, or maybe it makes physical-chemical treatment a viable alternative. You see, you put yourself in a different economic ball game if we are going to have to cover our waste treatment plants. So, this has been a strong issue with us and I was glad to see Chuck come across with the same kind of concern.

Ralph Scott pointed out several omissions in water balance and pointed out that we must consider the aerosol problem and brought up the point of entomology. Here again, all these problems have been recognized and we have tried to get bits of information one way or another.

This brings up a point which I think has been stated, but which I don't know whether was clearly understood. Basically, the Muskegon research grant didn't do all the things we felt were necessary. So we had some funds available through Regional sources which we have determined should be used in support of this project because of its impact upon the Great Lakes. That is how we got some research money for Michigan DNR which they then used to contract with Michigan State and with the University of Michigan to do additional work for the project. This wasn't a basic part of the original Muskegon grant; this was extra money that we have persuaded people should be spent to study impacts on soil, groundwater, and surface water.

In connection with Ralph Scott's concerns on industrial wastes, I would suggest that we have another site at Whitehall with the industrial waste problem. We don't have any research money for that site. We don't expect to obtain any funds under resources available to the Region, but it certainly is an interesting site and it has an interesting challenge for a sticky industrial waste problem. So, Ralph, if you know any way of persuading anybody that they should take a look at another problem, I suggest you take a look at the Whitehall problem.

Finally, I want to thank the people of Muskegon for hosting this session. I think they did a marvelous job. They have given us a very fine facility to hold our meeting. We appreciated the hospitality room and the transportation and the tickets to the Bob Hope Show. This sort of thing doesn't happen very often in our research meetings and it certainly flavored this one very nicely and again, we appreciate it very much.

I also want to to extend a note of strong appreciation to my own staff, to John Walker, to Steve Poloncsik and to Ralph Christensen because I did them a real dirty trick. The need for this conference was suggested by Curtis Harlin at our quarterly Research Advisory Board meeting in July. I suggested that we should have this meeting this fall. Everybody agreed with me and said great, this is a good idea and so I said fine, I am going on vacation. And I turned the responsibility over to John and to Steve and to Ralph and they did all the work in putting this together. I think that if there is any credit due, along with Ara Demirjian and the County people, all the credit goes to them. So I think this was a very excellent conference, I appreciate all of you coming, and I appreciate all of the inputs we have had. I certainly invite any further criticism, comments, or suggestions from you and I hope that we have your continuing interest in this project in the future.

Thank you very much.

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16. ABSTRACT

This Review Conference held September 17-18, 1975 was to provide data on the Muskegon County, Michigan Wastewater Treatment System. The operation of a municipal-industrial collection system, an aeration system, holding lagoons, and a spray irrigation system are discussed. Principal investigators of the project outline their progress from 1969-1975. Federal, State, and local government agencies are represented as to their views of the Wastewater Treatment System. Government officials, consultants and the academic community are asked for their views on research that they can see is needed to enhance the value of the project, and help to advance the status of the art in wastewater treatment on land.

The Conference discussed agricultural engineering and agricultural management of wastewater utilization, soil monitoring, groundwater monitoring and plant uptake studies. Lake monitoring, modeling and economic studies are included.

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